

MICROCOMPUTER-ASSISTED SITE DESIGN IN LANDSCAPE ARCHITECTURE:  
EVALUATION OF SELECTED COMMERCIAL SOFTWARE

by

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## CHAPTER 1 INTRODUCTION

Over the past ten years, computers have moved out of the once exclusive domain of technical professions and into the mainstream of affluent society. Much of this computer acculturation has been through the availability of low-cost, powerful microcomputers and commercial software which require little or no programming experience on the part of the user. Personal computing has become much like driving an automobile--the operator may not understand the internal workings under the hood, but knowing how to properly operate and maintain the vehicle are the main requirements for travel. Like early attitudes towards the automobile, microcomputers which were once considered a novelty have rapidly become a necessity offering unmatched convenience and productivity.

A large share of microcomputer impacts have been in business and engineering applications. Word processing as an enhanced typewriter has probably enticed more people into personal computing than any other single application. As a business, landscape architecture has certainly benefited from the ancillary use of business software. Landscape architecture, as a design profession, continues to be predominately expressed through pencil and paper.

Software written to assist designers is complex--and generally expensive--because of the requirements of interactive graphics, high-level mathematics, large databases, rapid processing, and ease-of-use patterned after design habits. Not surprisingly, most of the computer-assisted design (CAD) software available today has descended out of high-dollar market groups such as the automotive and aerospace industries, as well as the architecture profession. Moreover, many of these sophisticated CAD packages have been written for mainframe and minicomputer systems and have only recently begun to be down-sized for execution on less-expensive microcomputers.

A documented need exists among landscape architects for computer-assisted site design (CASD) software that will augment design visualization skills and confirm construction feasibility through engineering calculations. Previous research by Robert Symser (1984) has suggested that an idealized CASD package written for landscape architects should be based on the triangulated irregular network model for graphically representing landform. The CASD package should also be structured around design modules which permit the sharing of common site data.

The impetus behind this paper is the need to evaluate and communicate the potential usefulness of representative landform graphics and earthwork calculation software that is currently available to landscape architects. Chapter Two provides an overview of five overlapping areas of landscape architecture in which microcomputers are currently being used, or are

expected to be used in the future. The chapter continues by providing in-depth discussion of the computer as a design tool. Documenting the need for software evaluations is presented in the remaining pages of the chapter which cite results of a national survey conducted among landscape architectural and multidisciplinary firms (Clement, 1985).

Chapter Three presents the evaluations of commercial software marketed by three companies: CIVILSOFT, MFE Associates, and PacSoft. CIVILSOFT offers a broad range of civil engineering programs, but the evaluation focuses on two programs for generating topographic contours and calculating earthwork. Likewise, MFE Associates offers numerous programs applicable to landscape architecture, but the evaluation concentrates on the EARTHWORKS II program. PacSoft markets integrated digital terrain modeling programs under the TOPOGRAPHY system. Format throughout the chapter consists of software descriptions followed by the five evaluation categories of Performance, Ease-of-Use, Error Handling, Documentation, and Application to Landscape Architecture.

In the final chapter, attention is directed at comparing the strengths and shortcomings of the evaluated software in relation to an idealized CASD system. Three digital terrain models are discussed with a special emphasis on the triangulated irregular network model perceived to be the most promising data structure for coding the idealized CASD system. From the viewpoint of a landscape architect user, the idealized CASD system is described in terms of three-dimensional graphics, integration of modules, interactiveness, and ease-of-use. The chapter and paper concludes with a brief discussion of possible CASD development strategies which are intended to help direct continuing research.

## CHAPTER 2 OVERVIEW

Humans have always fashioned and used tools to enhance power, supplant weaknesses, extend limited senses, and provide new means of communication. For landscape architects, a pencil, a piece of paper, and a buoyant imagination have traditionally been the venerated design tools of the profession. Soon the computer may have to be added to that list of tools.

Compared to other professions, though, the computer has entered and impacted the field of landscape architecture rather slowly (Fabos, 1983). Widespread applications in the professional practice setting have only become apparent since the introduction of microcomputers in the 1970s. Concurrent use of commercially-available software has also transformed the convenience of personal computing into a necessity for performing many traditionally routine and labor-intensive tasks.

The microcomputer is without doubt a powerful and useful tool. Yet, despite inflated claims by some commercial advertizing, microcomputers are not revolutionizing all areas of every profession. At this point in time, microcomputers have not significantly impacted landscape design--the principal essence of landscape architecture. This contention is supported by several computer-use surveys, the most notable conducted by Paul Anderson (1984) and by Laurence Clement (1985). Apart from known groups such as the U.S. Forest Service which is doing computer-assisted landscape modeling for timber management and other specific applications, the typical landscape architect does not perform landscape design modeling on a computer system. Responses of computer use for design activities do not confer margins of effectiveness, time efficiency, or profitability. At this time, computers may be perceived by the optimists as a tool or by the pessimists as being a diversionary toy.

### IMPACT OF MICROCOMPUTERS ON LANDSCAPE ARCHITECTURE

How has the microcomputer impacted the profession of landscape architecture? To distill that question into a manageable form, project work performed by landscape architects and their associates are reviewed in five overlapping areas: Business Tasks, Geographic Information Systems (GIS), Engineering Calculations, Drafting, and Landscape Site Design (Figure 2.1).



Figure 2.1 - Five overlapping areas of landscape architecture in which microcomputers are currently being used, or will be used to a greater degree in the future.

## BUSINESS TASKS

Business tasks are the primary activities that commence even before a project contract has been accepted. Specific tasks include correspondence, cost estimation for design services to be provided, gathering and filing pertinent site/zoning information, project planning, personnel scheduling, and possible bid preparation. Once a project is secured, the business side of any landscape architectural firm demands on-going attention towards a number of internal management and accounting activities: preparation of memorandums, document filing, information retrieval, updating general ledgers, executing accounts payable, accounts receivable, payroll, and possibly inventory accounting. Toward the later phases of the project, working time is directed at specification writing and a gamut of project closing business procedures. For non-design projects, a large share of time may be spent preparing technical reports, scenic assessments, or feasibility studies. It is obvious that the many forms of written communication are an inevitable part of landscape architectural practice.

Of the five major impact areas, microcomputers by far have had the greatest effect on expediting the business aspects of the landscape architectural profession. Much of the rampant growth of the microcomputer industry was fostered by low-cost business application software which appealed to a huge new market of non-scientific users. Sophisticated word processors, spreadsheet programs, project management programs, information filing and retrieval software, and accounting packages have proven themselves to be generally time and cost effective.

In a market survey of 308 randomly selected business companies based in southern California, Nevada, Arizona, and Hawaii, it was revealed that 73% of 151 large corporations (most of which are publicly held and average \$133 million in annual sales) surveyed own microcomputers, while 43% of the 157 smaller companies (most of which are privately held and average \$3.6 million in annual sales) own microcomputers (Houlahan/Parker Marketing Research, 1984). If these percentages hold true for other areas of the United States, it is not surprising that competitive commercial software companies are trying to capture this lucrative market by offering increasingly sophisticated business software at affordable prices. The trickle down effect has had a commensurate impact on the business side of landscape architectural practice as well. Up to thirty-three percent of all recently surveyed landscape architectural firms of all sizes indicated that microcomputers were being used as a business tool (Clement, 1985), with word processing representing the single greatest business use.

Word processing programs are evolving into a machine-based technical assistant by not only providing extensive text editing abilities, but providing supplemental aids such as spelling checkers, electronic thesauruses, and outline idea processors to help organize and express thoughts to be communicated. New trends in word processing are moving towards even greater emulation of dedicated systems and software integrating word processing, spreadsheets, data management, and graphics programs all operating within a host environment where data can be shared (Martin, 1985). Multi-windowing, pull-down menus, integrated software, and cursor positioning "mice" are all setting new ease-of-use standards.

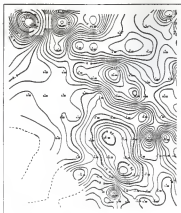
## SITE ANALYSIS AND GEOGRAPHIC INFORMATION SYSTEMS (GIS)

Knowledge and analysis of surface and subsurface site conditions with respect to intended land uses provide the contextual basis for sensitive site planning. The impacts of computer-applications in local and regional site analyses have predominately been through geographically-based information systems (GIS) in which spatial data are stored, processed, and analyzed. Geo-referenced data can be gathered from a variety of sources: U.S. Geological Survey digital topographic tapes (U.S. Geologic Survey, 1983; McEwen, 1979; Payne, 1983), LANDSAT scanning tapes (Holkenbrink, 1978), digitized soil maps from the Soil Conservation Service, local assessor's records, census tapes, or any other spatial data conveyed in digital format. Mapped output, as shown in Figure 2.2, can take the form of isolines connecting points of equal value, shading discrete areas with different print character symbols (choropleth technique), or graded shading of continuous data (dasymetric technique). Three-dimensional displays of topography with superimposed classifications of soil types and vegetative cover have been demonstrated by Junkin (1982). Geographic information systems are used for a multitude of applications including land-use inventories (Mitchell and others, 1977), landscape planning studies (Joyner and others, 1980), scenic assessments (Travis, 1975), forest management (NASA, 1981), water resource management (Campbell, 1979), and socioeconomic studies (Tom, 1979). Interpretive analysis often involves producing maps in which different data types are weighed according to a scale of importance and then overlaid to form a composite graphical image.

Low resolution of geo-referenced data has generally confined its use in land planning for analyzing large-acreage sites or regional areas. Public agencies controlling large land areas were therefore among the first users of geographic information systems. Using the parlance of Killpack (1982b), current users are found in the "soggy" market of planning and management groups, and the "solid" market of paper companies, utility companies, federal agencies, large cities, and research groups. The differences between soggy and solid markets are determined by what degree a GIS system can be cost-effectively used to perform routine, quantitative tasks.

Cutbacks in government subsidies have caused a shift in financing research and development formerly emerging from public and academic environments to the private sector. Investments by companies such as Autometrics, Computervision, Intergraph, Gibbs and Hill, IBM, and Sperry Univac are aimed at capturing new markets of diversified user groups (Killpack, 1982b). In many instances, scaled-down versions of larger GISs are being produced.

Apart from some landscape architects who work for public agencies and universities, use of geographic information systems has remained on the periphery of the profession (MacDougall, 1983). Lack of use often accrues from the inability to obtain the digitized data from public sources for a particular site under analysis. For small sites, it may even be necessary to build the data base at considerable time and expense. Lack of microcomputer GIS use is also attributable to hardware limitations. Geographic information systems require extensive processing and large amounts of data storage—two factors which until recently, have restricted GIS adaptation to microcomputers. These restrictions should become less pronounced be-



- a) Topography is often graphed through the isoline technique of connecting points of equal value or elevation (Calcomp).



- b) Occupied structures in the state of Connecticut (1960) are differentiated by percentage categories through the choropleth shading technique using print characters. (Dougenik and Sheehan, 1979, p. V-23).



- c) Landcover classifications for Union County, New Jersey, are plotted from July 1976 digitized LANDSAT data using continuous shading of gray levels characteristic of the dasymetric technique (Mills and Dwyer, 1980, p.162).

Figure 2.2 - Geo-referenced data can be depicted through (a) isolines, (b) print symbol shading, or (c) continuously graded shading.

cause of the introduction of 32-bit microprocessors, concurrent processing advances, and the availability of high density hard disks. The impact of microcomputer-based thematic mapping for small-area analysis and site design will likely continue to be minimal, however, until more extensive data bases are compiled at the state, county, and municipal levels.

## ENGINEERING CALCULATIONS

One of the earliest impacts of microcomputers on landscape architecture has been in performing engineering calculations. Microcomputer programs descending from early mainframe FORTRAN programs, but now written in other high-level languages or efficient assembly language, have superseded speed and data limitations posed by handheld calculators. Commercial programs mainly written for civil engineers are available for a wide range of applications including surveying, road alignment, earthwork calculations, slope and runoff computations, sun and shadow paths, structural analysis, and piped utility systems. Some landscape architectural firms do their own in-house programming for a specific application for which commercial software is either not available, or is unsuitable.

Most engineering programs are not integrated as part of an interactive design package. All too often, engineering calculations are a post-design activity used in preparation of construction documents. Calculations confirm feasibility, but are not generally used in a rigorous search for optimum design solutions which satisfy engineering requirements while minimizing material costs. In practice, optimization is difficult to do since design decisions are premised on interrelated site variables in which any design change implicates analysis elsewhere. A common example is how landform grading influences earthwork quantities, vertical road alignment, and gravity-dependent utility systems. Non-integrated programs limit re-iterative "what-if" scenarios aimed at optimum design solutions.

## CONSTRUCTION DOCUMENT PRODUCTION (DRAFTING)

To a lesser degree than business and engineering applications, computer-aided drafting (CADrafting) is beginning to register impact in reducing the time spent producing landscape construction documents. The major disciplines leading this area have been architects and engineers working in the mechanical, electronics (printed circuit board layout), industrial, and aerospace fields (Hopper, 1984). In the late 1970s, software companies like Computervision, Applicon, Calma, Gerber, and others released products for automated drafting. Today, in a recent survey conducted by the American Institute for Design and Drafting, 42 percent of the respondents (unidentified in source) indicated they were using some form of computer graphics. Additionally, 81 percent indicated they would be relying upon computerized drafting systems within the next five years (Schwendau, 1984).

Many of the automated drafting systems are driven by minicomputers costing between \$40,000 and \$80,000 (Engineering News Record, 1985). Operators draw on a screen, digitizer, or some other input device in much the same way as on a conventional drafting board. The difference is that the operator is creating a digital drawing file in which it is easy to inter-actively store additions, delete drawn areas, or make modifications. In

addition, many systems provide a library of standard symbols repetitively used for a particular drawing application. Scaled-down versions of these minicomputer systems are becoming more widely available for microcomputer drafting stations costing as little as \$20,000 (Appendix A).

While many architectural and engineering companies have cost-effectively used CADrafting systems for years, a concomitant impact on landscape architectural practice is not as evident. Landscape construction detailing incorporating regular geometries such as straight lines, circles, arcs, and polygonal facets is well adapted for CADrafting, but free-form curves and one-of-a-kind designs without repetition of graphic primitives, erodes the production advantages offered by computers. (One area of possible impact is the layout of high density housing where clustering arrangements are often flip-flopped or varied only slightly.)

## LANDSCAPE SITE DESIGN

Development of computer-assisted site design software for landscape architects has generally been eclipsed by efforts to refine CAD hardware and software already available to larger, more financially lucrative design professions. Landscape architects have expressed interest in computer-assistance for site design (Clement, 1985), but their specialized practice requirements and relatively few numbers have failed to attract the attention of commercial software companies. Technical complexities inherent in integrated software structuring and three-dimensional modeling techniques have also dampened development of site design software from within the profession. Very few landscape architects have the time, or the requisite computer background to successfully plan flowcharts and code complex mathematical algorithms.

Computer-aided design, as something more than just computer-aided drafting, couples engineering calculations with sophisticated two- or three-dimensional computer graphic displays that can be interactively manipulated. Current CAD software used in the architectural and engineering communities is a modeling tool far advanced from the early progenitor program, SKETCHPAD, developed by Ivan Sutherland in 1963. Financial support by automotive and aerospace industries was the main driving force behind CAD development because it enabled visual modeling for design aesthetics combined with engineering calculations for stress, air-flow, and other tests. Pioneer architectural firms like Skidmore, Owings, and Merrill also began designing buildings by creating computer graphic models that could be visually transformed and mathematically tested for structural integrity (Architectural Record, 1980).

Developments in computer graphic algorithms have supported new software and applications. Wireframe graphic models composed of point-to-point connections underwent early enhancements like hidden line removal and clipping of line segments. Continued advances produced poly-faceted shading, smooth (non-faceted) Gouraud shading, and antialiasing techniques (nonjagged diagonal lines). Computer graphics are approaching even greater realism through specular (mirror-like) reflections, reflections through transparent surfaces, shadowing, and textural effects (Hatfield and Herzog, 1982).



Computer modeling does not need to be static. Research in animated computer graphics, substantially financed by Lucasfilm and other cinema companies, is portraying realism through perfect perspective, smooth uniform shading, and complex motion (Sorensen, 1984). For landscape architects, the outfall of this research may eventually mean that designers will be able to simulate walking or driving through proposed landscape designs of near photographic quality.

Microcomputer software lags far behind these state-of-the-art developments, and CAD software specifically for landscape architects is virtually nonexistent. Almost all microcomputer CAD systems designed for architects and engineers accommodate graphic image assembly through the combination of angular or conic sections of regular geometries. Sinuous curves and undulating topographic surfaces are much more difficult to graphically represent through simple mathematics. Editing these shapes, approximated by multiple line segments, is time consuming because each line segment needs to be erased, positionally recalculated, and then replotted (Geometric editing is easier on mainframe and minicomputer-based CAD systems which use Bezier splines associated with polygonal vertices to define curve shape). Faced with these incumbrances, landscape architects often find it easier and more time efficient to design as they always have -- with pencil and paper.

Site design software developed for landscape architects needs to entrain more than just computer graphics since design decisions do not exclusively depend upon aesthetic judgments. Computer graphic images should be mathematically tied to algorithms which automatically calculate quantities of earthwork or watershed runoff, topographic slope and aspect, utility gradients, or any other engineering task according to preset parameters. In this way, the software will function as an engineering consultant, freeing the landscape architect to concentrate on aesthetic concerns. Rapid and continually updated engineering calculations supporting a "graphic spreadsheet" will also help promote the consideration of more design alternatives. All areas of work performed by landscape architects are being affected by advances in microcomputer hardware and software, but it is the design aspects of the landscape architecture profession that will be most radically changed as the microcomputer is developed into an indispensable deskside tool.

## USE OF THE COMPUTER AS A DESIGN TOOL

Formal training in visual design aesthetics is one attribute that sets landscape architects apart from professionals trained in more technically oriented disciplines like engineering. In an applied sense, engineers are not excluded from design either, because anything that is physically created, ordered, or assembled is rarely amorphous. Aesthetic beauty and functionalism never need to be dissociated. Attentiveness to design is even more crucial where form is a marketable asset. For the automotive industry, even minor styling changes in a car body can result in millions of dollars gained or lost when trying to appeal to fickle buyers.

Design aesthetics will always remain a value judgment. As such, it will never be reducible to a predictable and purely quantifiable process like a mathematical operation. It is therefore not surprising that software written to assist designers has only been developed through great expense and effort. Past experience has shown that more software development progress is made when the creative processes of designers are studied rather than the end products they create. How much of design is a process and how much is an intuitive sense? Is the process of design typically systematic or disjointed? Can aesthetic judgments be severed from past personal experiences? How can ideas be more readily expressed in tangible terms? Perhaps some of these questions trespass into the study of artificial intelligence, yet they cannot be ignored when developing software as a designer's tool. Software that is not structured after the pattern of thinking and expression of designers will soon be discarded.

Design combines past experience, available knowledge, imagination, and intuition (Straub, 1982). The stream of processes collectively called design are ineffable to a large degree, but several tenets summarize what designers do. The origins of design are established through the initial activity of imagining where perceptual or sensory information is synthesized into a mental vision of something which did not exist before (Lockard, 1982). Thoughts comprising imagination elude empirical study because mental pictures are often fuzzy and merely suggest directions for continuing thoughts capable of being expressed. Design images rarely form in one cataclysmic blinding vision; rather, design advances through developing and refining ideas which enable smaller "creative leaps" (Zeisel, 1981).

Landscape architects, like other designers, externalize mental images through sketching, building models, photography, writing, or other expressive media. Choosing the most appropriate means of communicating ideas is just as important as the ideas themselves since the ultimate goal of design is physical creation. Once design ideas have been tangibly expressed, the Concept-Test Model (Lebewitz, 1985) allows designs to be accepted, modified, compared, combined, isolated, or eventually rejected. Evaluation also narrows the field of design alternatives that can be acceptably carried out. Personal experience suggests that there is no single best solution, but many recognizably poor solutions.

Filtered designs which reach a level of acceptability are normally versions of former designs that underwent modification because they failed to satisfy necessary functional criteria, or from the viewpoint of the

designer or client, were visually unacceptable. Design is a process of continual feedback and reappraisal. Not surprisingly, experienced designers have a highly developed ability to foresee consequences of design decisions before wasteful time and financial commitments are made.

Cycles of imaging, presenting, and evaluation continue until an "acceptable level of imperfection" is reached and the decision to build can be enacted. Researcher John Zeisel (1981) envisions the process as a spiral metaphor (Figure 2.3) which reflects the following characteristics of design: "1) designers seem to backtrack at certain times --to move away from, rather than toward, the goal of increasing problem resolution; 2) designers repeat a series of activities again and again, resolving new problems at each repetition; and 3) these apparently multidirectional movements together result in one movement toward a single action."

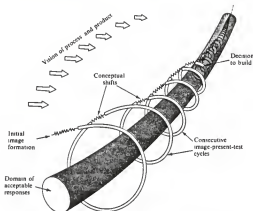


Figure 2.3 - The spiral metaphor of the design process (Zeisel, 1981, p.14).

Design is developed and expressed through alternate languages of thought: verbal/semantic, visual/graphic, and mathematical/quantitative (Adams, 1974). One of these languages of thought is usually more highly developed and comfortably used by an individual person than the other two. Landscape architects primarily design through graphic skills because of the effectiveness of visual communication. To a lesser extent, design is further defined through written specifications and construction calculations.

The numeric nature of the computer makes it a tool ideally suited for use in the mathematical aspects of design. Computers have also penetrated the language of graphics since even sinuous curves can be represented through graphic primitives defined by mathematical equations. Current computer graphics research exploring triangulated irregular networks, conography (irregular curves expressed through elliptical line segments, Cook and Koessel, 1983), and fractals (McDermott, 1983) will foster applications

particularly useful to landscape architects. Apart from word processing, the third language of verbal/semantic expression has been more resistive to computer assisted design. Nevertheless, binary logic is being applied towards research in artificial intelligence modeled after human reasoning and decision-making.

Use of a computer in design can be approached from one of three different levels: artificial intelligence (AI), knowledge-based expert systems (KBES), and computer-assisted design (CAD). Although hybrids may exist between the categories, a clear distinction needs to be made between the commonly interchanged terms, "artificial intelligence" and "expert systems". Summarizing the writings of artificial intelligence pioneer Marvin Minsky (founder and former director of the AI Laboratory at the Massachusetts Institute of Technology) and other AI purists, the following attributes can be ascribed to systems displaying artificial intelligence (Minsky 1985; Schank and Hunter 1985):

- self-initiated learning stimulated through curiosity
- the ability to analyze and solve new, different problems
- automatic memory organization and recall
- recognition of trivial information
- selective forgetfulness (as a method to conserve memory)
- episodic memory which influences or "colors" judgment
- recognition of exceptional conditions which alter normal decision-making processes
- the ability to make contextual inferences
- developed language and sensory abilities

Research into electronically-based artificial intelligence is inclined towards a better understanding of human thought processes, behavior, creativity, and learning. Although artificial intelligence is still in rudimentary stages, it is conceivable that landscape architects may one day be assisted by AI-based computers serving as a technical consultant with limited reasoning ability. The human landscape architect will be put in the position of being a teacher to a computer system which incrementally assumes more design responsibility as its database expands and decision-making becomes more refined through conditioned learning. Succinctly, the computer is taught to learn and build its own knowledge base rather than recite programmed responses extracted from a humanly constructed database.

Knowledge-based expert systems (KBES) are a class of computer programs utilizing hierarchical decision trees patterned after responses given by human experts who reveal the rationale underlying their decisions. Protocol analysis enables a KBES to solve narrowly defined problems on a level congruent with an human expert. Unlike linear sequencing of a conventional computer program, a knowledge-based expert system (KBES) employs forward chaining (working from known facts towards a goal), backward chaining (determining if facts support a hypothesis or goal), means-end analysis, and agenda control (ordering by a priority rating). What a KBES computer cannot do is employ plausible inference and reasoning from incomplete or uncertain data (Michaelson, Michie, and Boulanger, 1985).

In technically oriented professions like engineering, application of knowledge-based expert systems has been moderately successful. One such knowledge-based expert system named HYDRO has been developed for civil

engineers wanting to estimate infiltration rates based on judgments relying on information concerning vegetative cover, soil type, and soil depth (Fenves and others, 1984). Instead of just processing information, the HYDRO system makes engineering decisions much like a human expert.

To construct a similar KBES for landscape architecture, it is first necessary to morphologically define site design as conceptually outlined by Koberg and Bagnall (1974). Preparation of Table 2.1 shows one route of morphologically connecting various site design alternatives. The table is site specific and greatly simplified, but it depicts how elements of site design can be categorized. For each site attribute listed horizontally, a corresponding column of design alternatives is listed vertically. It is doubtful that designers consciously consider all of these alternatives when designing, or are even able to articulate intuitive senses of aesthetic judgment. The table does provide systematic order amenable to computer methods.

Permutations resulting from different routes connecting design alternatives can be generated by a computer. In application, though, the vast majority of connecting routes will be invalid because of internal conflicts. Design alternatives are highly interrelated and contingent upon decisions previously made; for example, a modest budget will eliminate the choice of granite as a paving material in most localities. If a human designer must examine all of the computer generated combinations of design alternatives and cull out those that are valid or feasible, then time savings are greatly diminished. The rationale determining why certain decisions are made is at least as important as considering a plethora of design alternatives. It is imperative that KBES researchers concentrate on structuring a weighted value system to guide computerized decision-making. Furthermore, value weightings must be changeable for every project and prefaced on early decisions which constrict the range of subsequent options.

Another problem of KBES construction is compiling a database having sufficient depth and breadth. Human designers have a lifetime of experience to draw upon in which minute details affecting design decisions can be mentally triggered by associative recall. Building an equivalent computerized data base would be literally a lifelong process. Kevin Lynch (1974) also points out that design diversity can descend from "misfit" conditions—site difficulties—that force alternate approaches and adjustments in priorities. Turning a site liability into a design asset requires innovative thought—something a computer does not easily perform. Systematic approaches to site design should not always be viewed pejoratively. The process does provide objectivity which displaces intuitive, superficial ("gut level") choices that may be revealed as flatly wrong.

The lowest, but most immediately feasible, technical level of computer use in design places the computer as a tool in the hands of a human designer. In this context, the computer assumes a subservient role of providing graphic assistance, retrieving information, and executing engineering calculations as requested by the human designer. The designer retains full control of the design process by establishing design criteria, orchestrating actual design, and evaluating the products. Concentrating efforts on computer-assisted design is the context in which the software evaluations of Chapter 3 will be based. The software being reviewed represents a

Table 2.1 - Physical site characteristics and design alternatives.

DESIGN HOPKINS Tadecreek II Washington, Kansas				
PHYSICAL SITE CHARACTERISTICS	Grass Landcover	Sheet Drainage	Uniform Slopes	Wind Influences
Alternatives	Preserve grass open space Plant isolated trees Plant tree groupings Forestall	Retain sheet drainage Concentrate water in swales & drain off-site Create retention/detention ponds	Maintain uniformity Introduce swales & berms subtle emphasized	No deterrent (sweeper breezes) Limited windbreak Dense windbreak
FUNCTIONAL CONSIDERATIONS	Parking	Walkway Materials	Circulation	Lighting
Alternatives	Streetside parallel parking Streetside single bay Bay penetrating site single bay double bay multiple (70, 60, 45 dep.)	Soft surfaces grass cedar chips Hard surfaces asphalt concrete brick wet pavers	Vehicular drive with dropoff shallow site penetration deep penet. w/ drive & 15' Pedestrian wide 1/6', axial walkway central plaza area w/ narrow (6'x) peripheral walks	No lighting provided Standards rustic machined/cast Lushare type spherical rectangular other Light type metal halide sodium vapor other
PLACED SITE ELEMENTS	Community Building	Swimming Pool	Tot Lot	Tennis & Multi-purpose Court
Alternatives	Design open-air semi-enclosed enclosed Materials cedar wood brick native limestone Configuration rectangular L-shaped other	Size recreational (20' x 40') recreational (30' x 60') Jr. Olympic (45' x 75') Configuration rectilinear L-shaped T-shaped Location east, close to parking north, protected by windbreak & open to sun?	Ground surface sand wood chips Equipment commercial equip. (steel) timber play structure Variety in equip. selection Equip. selection supportive of central theme	Size fullsize half-court Surfacing asphalt concrete resilient synthetics Layout row along north Pl. staggered paired
DESIGN CONSIDERATIONS	Character & Maintenance	Layout Form	Scale Hierarchy	Plant Massing
Alternatives	Wild, no maintenance Rustic, some maintenance Informal with mod. eqvites Formal, maintained	Rectilinear Rectilinear - 45° Irregular Radial Arc-tangent Curvilinear	Large node surrounded by smaller nodes Linked nodes of equal size Linear gradation of nodes	Direct sight lines Define space Provide shade, texture, color, & aroma
UTILITIES	Electric Service	Sewer	Storm Drainage	Water Availability
Alternatives	No service Overhead service Underground service On-site generation	Septic fields Holding tank Piped to city treatment	Connect to existing off-site storm drainage system Keep all drainage above surface	Residential supply tap On-site well Treated surface water

Notes: Design decisions are based on zoning regulations, site context, economics, aesthetics, and conformance to design intent.



narrow band in the design process spectrum (Figure 2.4) that may be impacted by increasing computerization.

Computer-assisted design should not be considered a panacea for poor design skills. The best designers will continue to create the best designs, whether they elect to use a computer or not (Bazjanac, 1975). Attempts to improve the human-machine dialogue and power of computer-assisted design software will, however, give designers an unprecedented tool for helping them more effectively express their ideas, consider more alternatives, and make more informed decisions.

## THE NEED FOR SITE DESIGN SOFTWARE

Surveys conducted for the American Institute of Architects (AIA, 1983), the Design Research Institute at Iowa State University (Anderson, 1983), and the American Society of Landscape Architects (Clement, 1985) have all documented that a very small percentage of architects, planners, and landscape architects routinely use the computer as a design tool. Most recently, the Clement survey shows that 27.7% of responding multidisciplinary firms of all sizes use a computer for design development drawings. Narrowing the sample to just landscape architectural firms, only 6.1% of the responding firms indicated that computers were used for the same purpose. Lack of computer use for design activities does not imply lack of need. When queried concerning present computer needs, a composite of multidisciplinary firms indicated Planning/Design and Computer Graphics as the top two need categories. Similarly, for a composite of landscape architectural firms, the same categories were the respective second and fourth most frequent choices among computer use needs. (Survey excerpts are presented more fully in Appendix B).

Although no statistical follow-up was made to determine why the microcomputer is not widely used as a design tool by landscape architects, insights were revealed in open-ended survey questions linking practice needs to microcomputer use. Selected responses included:

"[Computer use is] not cost effective"

"Desire to know more about computers and their relationship to LA design"

"There is a tremendous lack of appropriate software"

"There does not seem to be hardware or software suitable for our practice and firm size that is affordable"

"Adapting software to the needs of the LA and writing new programs seem to be our greatest need at this time."

"Software development and the sharing of such information is our (the profession's) critical problem."



"The technology now exists to do some fantastic work on computers if the right equipment is gotten with the hands of the right people. Our needs include the availability of appropriately priced hardware and software which will allow more of the preliminary design processes to be accomplished cost effectively on the computer."

"Need [exists for] evaluation and knowledge of worth of available software."

"I have poured through computer journals and find it hard to locate usable software for LAs -- and find it hard to understand software programs which may be helpful."

(Clement, 1985, pp. 114-118).

Landscape architects recurrently expressed the need for knowledge of software availability, performance, and compatibility to landscape architectural design. Considering the tremendous proliferation of microcomputer software that has emerged in recent years, keeping abreast of new software offerings related to a particular application can be a formidable task in itself. Computerized searches of software databases (listed in Appendix C) such as CompuServe, The Source, and The Knowledge Index are a reasonable place to begin. Numerous printed software directories (listed in Appendix D) are also available: Microcomputer Index, Periodic Guide for Computerists, and the Software Catalog among others. Searchers should often peruse professional journals in related fields such as architecture and civil engineering. Entire issues are sometimes devoted to software developments and availability.

An even more challenging task than locating appropriate software is evaluating its quality and usefulness. Some software companies offer programs that can be rented on a trial basis or offer demonstration disks that can be purchased at a nominal cost (sometimes these disks are merely electronic brochures instead of actual demonstrators). Even though most software can be returned if the user is unsatisfied, few landscape architects have the time, patience, or money to sample numerous software packages of unknown performance. Software reviews like those published in InfoWorld and other popular magazines focus on software that will appeal to a wide market of users--and readers. The American Society of Landscape Architects could perform a valuable service to landscape architects by publishing software reviews written from within the profession for specialized applications (Clement, 1985).

Purchasing software for common business or engineering applications should be considered preferable to in-house programming. Even if programming is within the technical expertise of the firm, it is generally not time- and cost-effective to write and debug programs if satisfactory software already exists. Computer-based spreadsheet templates can be set-up for most business or engineering problems, negating the need for dedicated programming. The advantages of spreadsheet formatting and built-in file management operations alone represent a considerable effort of comparable programming.

For specialized landscape architectural applications for which commercial software is unavailable, in-house or hired programming may be the only alternative. Relatively simple engineering problems or computer graphic routines can often be programmed by experienced in-house personnel, but firms should be prepared for large time commitments devoted to program development, debugging, and documentation. For one-time, nonrepetitive applications, in-house programming will likely not be worth the effort. Special attention should also be directed at making sure other personnel besides the programmer can operate and manage the software. Users accustomed to sophisticated and "user-friendly" commercial software have high expectations which diminish their patience for cumbersome or poorly documented programs.

Large multidisciplinary firms like Skidmore, Owings, and Merrill (SOM) and Hellmuth, Obata, and Kassabaum (HOK) have pioneered much design oriented software since they have business volumes of sufficient size to warrant employment of full-time computer specialists. According to Douglas Stoker, head of the Chicago SOM computer group, the key to economical computer-use is establishing a data base in which information can be shared to produce different end products: "You want to avoid the discrete event approach where you do a drawing, take it out and throw the data away." (Architectural Record, 1980). By structuring data bases for multiple applications, SOM is able to use the same data to generate perspective drawings, produce a set of working drawings, assist in structural analysis, calculate energy loads, or simply make a quantity estimate. Interestingly, because of the urgency of application needs, SOM continues to contribute original research to the field of computer graphics and design (Mirante and Weingarten, 1982).

A telephone conversation with Ted Spaid\* of HOK in St. Louis highlighted that much of their effective use of computers is a result of not segregating designers and computer specialists. Better decisions are made because designers actively participate in computer modeling studies. As far as can be determined, however, computer-use by these firms is oriented more to architectural structures and capabilities for interactive site design modeling is far more limited.

Where does this leave landscape architects? At present, no computer-assisted site design software package integrating landscape layout, grading, road alignment, and piped utility systems (such as drainage and irrigation) displayed on a three-dimensional landform image has been specifically developed for landscape architects. Constituent parts of a computer-assisted site design (CASD) package exist as programs dedicated to specific engineering applications like contouring and earthwork estimation. Even for small landscape architectural offices, use of these programs offers definite economic advantages compared to performing the same tasks through manual techniques. Use and support of these existing programs by landscape architects will also encourage software companies to pursue development of an integrated CASD package.

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\* Personal communication (May 15) with Ted Spaid of Hellmuth, Obata, and Kassabaum (HOK) located in St. Louis Missouri.

## CHAPTER 3

### EVALUATION OF COMMERCIAL SITE DESIGN SOFTWARE

#### EVALUATION INTENT

Before developing computer-assisted site design software (CASD), it is expeditious to first evaluate some current software available in related professions. Landscape architects can learn much from the computer experience of architects and engineers. Landscape architectural design, rooted in construction feasibility, often parallels work done by civil engineers. Design decisions must invariably respect engineering principles underlying such activities as road alignment, grading and earthwork, underground utility systems (storm drainage, sewer, water distribution, and minor structural detailing such as retaining walls and wood decks. By training, landscape architects approach landscape manipulation differently than do engineers. Is software primarily developed for engineers directly transferable to the field of landscape architecture? What software modifications, if any, need to be made in either performance or ease-of-use? How feasible is it to upgrade and combine existing programs into an interactive software system for graphically modeling landform? Partial answers to these questions will be provided through an evaluation of several commercially available engineering programs.

#### SELECTION AND PROCUREMENT OF SOFTWARE

Since graphical landform depiction and site grading are central activities around which other landscape design concerns revolve, the scope of the evaluation was narrowed to a sampling of landform graphics and earthwork estimation programs. Software selection was also dependent upon compatible hardware systems available at Kansas State University. A final consideration was selecting software that could be run on relatively inexpensive mainstream hardware (costing less than \$10,000) usable for a multiplicity of different office activities--ranging from business to engineering/design tasks.

Three companies were selected: CIVILSOFT, MFE Associates, and PacSoft. CIVILSOFT was chosen because it has an established reputation among civil engineers and universities and has developed an extensive line of civil engineering software. Selection of MFE Associates, a corporation composed of landscape architects, provided insights from within the profession. PacSoft was selected as the third and final company because its software offerings are part of a digital terrain modeling system.

In November of 1984, proposals soliciting the loan of software for evaluation purposes were submitted to four software companies. The aforementioned three companies accepted the invitation to participate, and the software arrived at Kansas State in late December and early January. The subsequent evaluation was conducted in the first five months of 1985 and was completed in May.

## SOFTWARE EVALUATION CRITERIA

The evaluation was divided into two phases consisting of operational testing and a comparison inventory of software features. Operational testing followed the standard review categories of Performance, Ease-of-Use, Error Handling, and Documentation as found in the standard software review format of InfoWorld: Newsweekly for Microcomputer Users (published by CW Communications). A fifth category, "Application to Landscape Architecture" was added for this evaluation. Each generic category is more fully described below:

Performance: Performance is the most salient reason why software is purchased: "Will use of the software save time and money?" As one of the more objective evaluation categories, performance was measured in quantifiable terms like accuracy, image trueness, and speed. Unfortunately, software development personnel sometimes devote too much time ensuring performance while neglecting human engineering aspects. This consideration was looked at closely. In addition, an awareness should exist that performance can be measured against the intended use of the software, or relative to an expanded vision of possibilities.

Ease-of-Use: Landscape architects will be more apt to use microcomputers as a design tool if the application program is simple to use and time efficient to operate. This category focused on perceptions of how well users could interact with the programs.

Error Handling: The ability of software to handle user operational errors is often indicative of the quality of programming. Comprehensive error trapping procedures increase landscape architects' confidence in the operation and results of the software. Since most of the evaluated software has been marketed for a year or longer, errors originating in the coding have likely been discovered through rigorous alpha testing (in-company) and beta testing (by external groups) using techniques like those described by Beizer (1983). Reports of error handling deficiencies from this evaluation are expected to be received by the software companies as suggestions for future software enhancements.

Documentation: Since specialized engineering and architectural software is not generally available through a local vendor who can personally provide operating assistance, well-written documentation is imperative to the widespread acceptance and use of a given software package. Specific subcategory considerations included layout and format, content, writing style, tutorial section, and software support.

Application to Landscape Architecture: Written from a viewpoint within the field of landscape architecture, the last category summarized an opinion of perceived software usefulness for landscape design. More expansive perceptions of how well the software reviewed conforms to an idealized software package is provided in Chapter 4.

## TEST SITE DESCRIPTION

The software was evaluated using site data from a 5.1 acre tract of land within the Timbercreek II residential development located a few miles east of Manhattan, Kansas (Figure 3.1). The gently sloping, grassy site has been designated for recreational development. Amenities are phased, and at this time, a swimming pool and support building have been constructed. The General Development Plan shows eventual construction of a multi-purpose community building, four tennis courts, a multi-purpose court, tot lot, and parking for twenty cars (Figure 3.2).

Spot elevations were derived by interpolating backwards from an existing contour map produced and verified by B-G Engineering of Manhattan, Kansas. Computer contouring was also more realistically tested because the site had a localized berm, swale, and curbing that might not be picked up by regular grid sampling.

Sections were taken across the site at seventeen strategic locations (Figure 3.3). Estimates of earthwork were then prepared using the average end area method in which subcut and subfill areas were manually measured with a polar planimeter. Earthwork estimates and accompanying sections were resolved to a high level of detail to account for different volumes of topsoil stripped, topsoil replaced, and various pavement metals associated with play court surfaces, pool decks, walkways, and parking areas (Figure 3.4).

## COMMERCIAL SOFTWARE EVALUATIONS

### CIVILSOFT COMPANY

CIVILSOFT of Anaheim, California, offers a broad range of civil engineering software that has been in use by engineers and surveyors since 1976. Over thirty application programs are available which can be run on nearly every microcomputer using a MS-DOS, PC-DOS, or CP/M-80 operating system. Most CIVILSOFT programs are written in machine code instead of interpreted languages to speed program execution. Software evaluations were performed on the CONTOUR and EARTHWORK II programs.

#### CONTOUR Program

In its most common application, the CIVILSOFT CONTOUR program generates a plan view map of contour lines which connect points of equal topographic elevation. The program consists of three integrated subprograms: CINPUT, CONTOUR, and CPP.



# TIMBER CREEK II RECREATION COMPLEX

TIMBER CREEK II HOME OWNERS ASSOCIATION

MANHATTAN

KANSAS

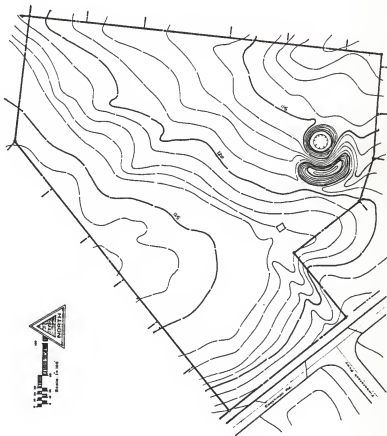


Figure 3.1 - Timbercreek II Site - Existing Conditions



## TIMBER CREEK II RECREATION COMPLEX

TIMBER CREEK II HOME OWNERS ASSOCIATION  
MANHATTEN

KANSAS



Figure 3.2 - Timbercreek II Site - General Development Plan



# TIMBER CREEK II RECREATION COMPLEX

TIMBER CREEK II HOME OWNERS ASSOCIATION  
MANHATTAN

KANSAS

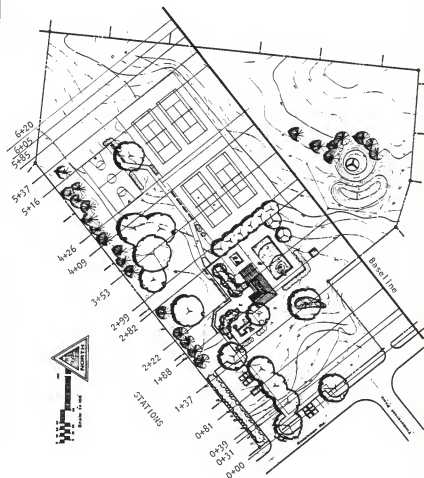
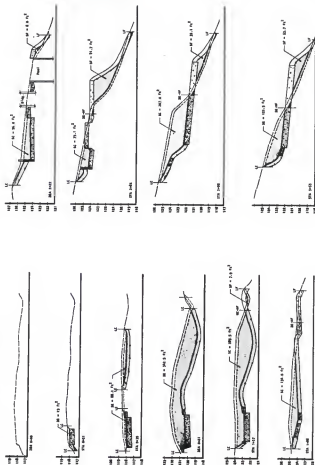


Figure 3.3 - Timbercreek II Site - Location of Cross-Sections



Figure 3.4 - Seventeen Cross-Sections

# **TIMBERCREEK II** Manhattan, KS Earthwork Estimate





## CINPUT Subprogram (CIVILSOFT) - Performance and Operation

The CINPUT (Contour Input) program accepts mapping data in a easting/northing/elevation (x/y/z) format. Data can be entered manually through the keyboard, or transferred from files already created from the CIVILSOFT COGO-PC program or from any user-defined x,y,z file following ASCII format. The CINPUT program also handles several utility procedures including data editing, loading files into memory, saving files on floppy disks, and setting program parameters that are later used by the plotting program. Data file editing can optionally be performed through any text editor or word processing program (such as the non-document mode in the word processing program WordStar).

Random topographic data are entered by inputting northing (y), easting (x), and elevation (z) values (Figure 3.5) for up to 750 data points. Label descriptions up to ten characters in length can also be attached to each point. Once the points are entered, partial or full data ranges can be listed ten points per screen, one screen at a time. To edit incorrect entries, it is first necessary to write down the point ID number from the screen listing and then enter the edit mode. Points can be edited singly or in ranges. Other submenu options allow editing of point labels or selective editing of elevations only. This last suboption is especially useful for appending elevations to points transferred from existing COGO-PC files.



Figure 3.5 - Axis orientation for x,y,z coordinates.

Program operation then proceeds to setting control parameters to be used in contouring and plot formatting (Figure 3.6). Control parameters permit the user to set minimum and maximum x, y, and z values, specify plot scaling, specify the contour interval and which contours should be plotted heavier, set the degree of contour rounding, and specify printing characteristics of point labelling. Since it is sometimes desirable to see which triangles the program used and how the contours were connected, a control item can be set to print the web of triangles over the contours. Grid ticks can also be printed over the contours according to an entered scale value. This option is useful as an aid to measuring horizontal distances across the contour map or for systematic horizontal control.

Program control is returned to the operating system for running the CONTOUR or CPP programs. Confirmation is required to protect against inadvertently quitting before data have been saved.

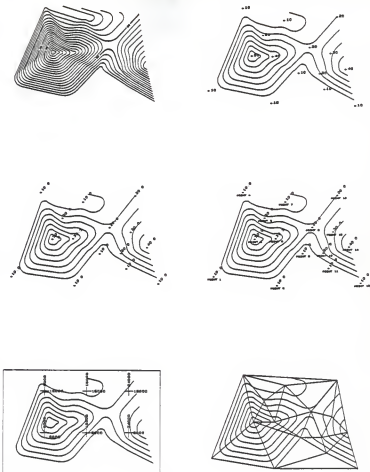


Figure 3.6 - CIVILSOFT CONTOUR plotting options (CIVILSOFT CONTOUR Documentation, pages A-9 to A-14).

## CONTOUR Subprogram (CIVILSOFT) - Description and Operation

The CONTOUR program performs the actual calculations necessary to interpolate contour lines between the points entered through CINPUT. Based on the system of triangulated irregular networks, the algorithm determines the best way to connect coordinate points to form a network of triangles through a two-pass process. In the first pass, the entire spread of coordinate points is swept and connecting triangles are formed. The second pass refines the shape of each triangle to approximate an isosceles triangle. Long, thin triangles near the outside site boundary are sometimes deleted since they would unrealistically distort the actual contours. Once an optimized triangular network is formed, the program interpolates contour interval crossings along the legs of each triangle. Elevations, along with the connectivity of the points, are then sorted, strung together, assigned a plot code, and finally written to an intermediate plot file.

## CPP Subprogram (CIVILSOFT) - Description and Operation

Contour plotting is performed by the CPP (Contour Plotting Program). Using parameters previously set through CINPUT, the CPP program plots contour lines which can be displayed on the screen, directed to an Epson printer with Grafrax, or directed to one of twelve different pen plotters having characteristics as shown in Table 3.1.

Table 3.1 - Characteristics of the twelve pen plotters supported by the CIVILSOFT CONTOUR program.

Plotter	Maximum Paper Size	Line Types	No. Pens	Type of Commun.
HP 7470A	8 1/2" x 11"	6	2	RS-232
HP 7475A	11" x 17"	6	6	RS-232
HP 7580A/B	22" x 34"	6	8	RS-232
HP 7585A/B	34" x 44"	6	8	RS-232
HP 7586B	34" x 44"	6	8	RS-232
Amdek DXY-100	8 1/2" x 11"	2	1	Parallel
Sweet-P	8 1/2" x 11"	1	1	Parallel
HI DMP-40	11" x 17"	9	1	RS-232
HI DMP-41/51	22" x 34"	9	1	RS-232
HI DMP-42/52	24" x 36"	9	1	RS-232
Alphaplot I	22" x 34"	6	8	RS-232
Alphaplot II	24" x 36"	6	8	RS-232

## CONTOUR Program (CIVILSOFT) - Performance

The most significant factor affecting performance of the CONTOUR program is its reliance on the method of triangulated irregular networks. By contrast, most available contour programs rely on terrain information organized in a rectangular grid system. Although relatively easy to program and compatible with early geographic information system (GIS) data bases (Honeycutt and others, 1980), grid systems are marginally suitable for terrain depiction. Since terrain elevations are only sampled at regular intervals, topographic features such as hilltops, ridges, and deep-cut swales may be missed if located in areas between the grid intersection points. If the grid spacing is scaled tighter to capture these features, then uniform areas will contain redundant points which consume excess computer memory.

Contouring based on the method of triangulated irregular networks can directly work on random coordinate points without assigning them to the nearest grid intersection. Sampled points can therefore be concentrated where needed to more accurately define terrain features which might otherwise be missed or distorted. Program efficiency is improved by CIVILSOFT's incorporation of a two-step radial sweep algorithm developed by Mirante and Weingarten (1982) of the Skidmore, Owings & Merrill architectural firm.

Two plots were performed. In the first plot, rectangular grid coordinates were entered so a comparison could be made with the PacSoft SMOOTH contouring program (Appendix F, Graph F.1). In the second plot, random points were added to demonstrate the effectiveness of a triangulated irregular network (TIN) in capturing topographic detail (Appendix F, Graph F.2).

Entering the x and y coordinates and elevations for 615 data points was a tedious and time consuming process. Digitizing data for the purpose of generating plan view contours is not applicable since mapped contours are the normal format required for digitizing. If field data are obtained and recorded on a grid layout, then input time could be reduced by digitizing a prepared acetate sheet of scaled grid points in which corresponding elevations could be entered through the keyboard. Additional random points could be either quickly plotted on the sheet and digitized, or manually entered for each x,y, and z value. Because the contour program offers no option for digitized input, it would be necessary to transfer digitized data through a user-defined file. When entering points on a regular grid, another time-saving option would be to write a short looped program that automatically generates x and y values from row and column positions multiplied by the grid scale. The user would only have to enter corresponding elevations and point descriptions. Random points requiring x, y, and z values explicitly entered through the keyboard could be added as necessary to more accurately define complex topographical areas.

The CONTOUR program contains the mathematical algorithms necessary for triangulated network formation and therefore requires no user input except the name of the file to be acted upon. For the test site represented by 615 points, 80 minutes were required for program

execution. Screen messages allow the user to follow the sequence of program operations as they are performed. The first displayed message can be confusing, however, because no disk drive light is on or other sign of action is evident as the computer internally calculates. A flashing, but unresponsive cursor may cause unwary users to use a <Ctrl Break> to exit a seemingly locked program. When the contouring sequence is finished, a helpful feature is the beep sounded to recall users who may be working on other projects while waiting on the program.

When using the CPP program, a contour pen plot of the 615 point site only required a couple minutes to complete. Plotting speed is dependent on the complexity of the contours and the hardware employed. Screen plotting is particularly useful for rapidly previewing contours, but no contour numbering or other special plot options are displayed.

For users who do not own a pen plotter, plots can be directed to an Epson dot matrix printer having Grafrax. Preparation for printing was found to be relatively long--typically in excess of 15 minutes--because a bit-mapped raster file must first be created. Further, near continuous operation of the disk drive was required to build a large raster file that consumed half of the disk storage capacity. Print quality of the contours was very uniform, however, with good resolution of details.

Compared to plotting with the printer, pen plotting was much more time efficient and required less disk storage space. Plot smoothness and quality was somewhat inferior to the printed plot, but can be improved somewhat by adjusting the pen pressure. No special plot features like contouring labeling could be obtained, but the problem was determined to reside with the computer-plotter interface.

#### CONTOUR Program (CIVILSOFT) - Ease-of-Use

The CINPUT program of the CONTOUR software is operated through a numbered menu. Choices are automatically executed negating the need to follow with a <Return>. After specifying the range of numbered x,y,z points to be entered, inputting the coordinates through the numeric keypad is a tedious and lengthy process. Mistakes cannot be immediately corrected because it is necessary to first finish the looped input sequence. Editing is more easily performed by using a word processor in which full screen file listings can be scrolled up and down for correction as needed.

When working with a large number of points, it is a good idea to enter the data in blocked ranges so it is possible to check input accuracy, edit mistakes, and build the data base by incrementally saving the information in disk storage. Users can ill afford accidentally losing a large data base compiled through considerable time and effort.

The boxed format of the contouring and print control data enables specified parameters to be rapidly reviewed in their entirety. Ease-

of-use for this option could be improved by converting the editing process from two steps to a single step. Numbered control data should be immediately selectable. Pressing numbered choices before pressing (E)dit will send the user back to the main menu.

Ease-of-use for both the CONTOUR and CPP programs can be considered good because minimal interaction is required on the part of the user. Both programs simply operate on previous data files established through CINPUT. A file directory is not automatically listed, but a directory can be called up by typing an "F". The program automatically handles file extension procedures.

#### CONTOUR Program (CIVILSOFT) - Error Handling

Of the three subprograms, human errors are most likely to occur when using CINPUT for entering point data and setting plotting control parameters. For each entry prompt, erroneous keystrokes were either ignored or recovery procedures were displayed. As described more fully in the next section, one major error occurred because the coordinate data were entered reversed. Having the user enter x and y values allows potential confusion, especially when the documentation is inconsistent. It would be much better if the entry prompts used the terms "easting" and "northing" instead of "x" and "y".

Another problem, or limitation, arose concerning trying to direct contour plots to the screen. The 615 data points defining the Timbercreek II site numbered less than the 750 point maximum allowed by the program, but it was found that contour lines could not be plotted on the screen for large files involving upwards of 3000 plot vectors. It was still possible, however, to direct contour plots of large files to the pen plotter. Overall, errors are infrequent when using the CONTOUR and CPP 7475 subprograms because human interaction is minimal during contour processing.

#### CONTOUR Program (CIVILSOFT) - Documentation

CONTOUR documentation consists of an 8 1/2" x 11" 3-ring notebook in which updated material can be added as it is made available. Overall organization is provided by a table of contents, but no index has been compiled. Program sections are not tabbed, but sections can be identified through a two-number page ordering system (section number followed by page number). Formatting could be improved by using multi-color highlighting of major section headings or critical information.

Program documentation is divided into five major sections: Introduction, Contour Input Program, CONTOUR program, Contour Plotting program, and Appendices. The first section summarizes salient program features and briefly describes data preparation. Content of the next three sections describe program features and operational procedures. Extensive appendices provide examples which help the user step through program operation using sample data files residing on the program



disk. Other important appendices include sample contour output, file structure, getting started procedures, error messages, plotting specifications, and technical notes.

The writing style of the documentation is clear and does not burden the reader with lengthy descriptions. For most users, familiarization with program operation should only require one to two hours. A major inconsistency was discovered, however, which caused confusion in entering data. Pages 2-3 and 2-4 state that "x" corresponds to northing values and "y" corresponds to easting values. Elsewhere in the documentation, and particularly in the sample data listing presented on page A-3, northings and eastings are correctly shown to correspond with "y" and "x" respectively. Because of the inconsistency, all of the x and y data were entered in reversed order. Correction of the coordinates through the CINPUT program would have required re-entering all the data. The data columns were interchanged through a fairly elaborate procedure (described in Appendix E) using WordStar and Lotus 1-2-3.

General questions concerning operation of the software can be answered by directly calling CIVILSOFT. Technical assistance requires slightly more time since CIVILSOFT prefers to collect telephoned questions and interrupt their programmers only once each day. When operating the program for the Timbercreek II test site, errors arose concerning lack of space for triangles in the outer loop and file corruption. Resolution of the problem took several weeks because the data disk was mailed to CIVILSOFT for file examination.

#### CONTOUR Program - Application to Landscape Architecture

Landscape architects use contour maps as the preferred method of representing topography and existing site conditions. Site design is implemented in part through a proposed grading plan which incorporates functional and aesthetic considerations. Contour data is available for most sites on U.S. Geological Survey quadrangle maps at a scale of 1:24,000. For smaller sites, preliminary planning can be accomplished by enlarging the U.S.G.S. map and verifying accuracy through field survey checks. Whenever contour maps need to be produced, most landscape architectural firms find it more economical to commission aerial photographers or professional survey crews to perform the job instead of producing the maps themselves. Use of the CONTOUR program by landscape architects for plotting topographic data is therefore expected to be minimal unless proposed grading is performed through spot elevations.

Landscape architects will probably find the program more useful for mapping data that are nontopographic, but is spatially related. Sample applications might include behavioral studies where the z value represents frequency of events (Figure 3.7). Contour maps, or better yet—three-dimensional contouring, can also be used in landscape construction for analyzing ordinal relationships between any two independent variables which determine a third dependent variable (Figure 3.8). Similar contour modeling can be developed for financial analysis.

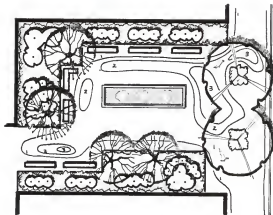


Figure 3.7 - A contour plot representing the frequency that users stopped to congregate in a hypothetical plaza. "Higher" isolines correspond to higher use (Computer contour plot has been graphically redrawn and enhanced with plaza features for clarity).

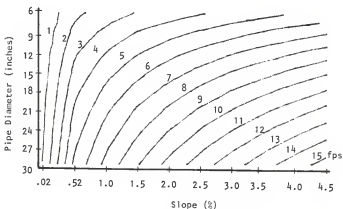


Figure 3.8 - A contour plot of the Manning Formula for pipe flow velocities in fps.

## EARTHWK II (CIVILSOFT) EVALUATION

EARTHWK II is a program designed to perform tedious and repetitive earthwork calculations for road design. In a single run, the program is structured to accommodate up to 50 cross-sections in which existing and proposed elevations are entered through the keyboard or soon-to-be released digitizer option. Subsequent earthwork quantities are calculated by either the average end area method or the prismatic formula method. Output includes cross-sections for each station, incremental cut and fill quantities between consecutive stations, and a summary mass ordinate table. Sample output is presented at the end of the chapter and in Appendix F.

### EARTHWK II (CIVILSOFT) - Description and Operation

EARTHWK II is a menu-driven program in which options are selected by entering the appropriate code number from the option listing. The largest share of user interaction is channeled through the first menu option of editing cross-sectional x and y elevation data which describe the existing and future grades. Fifty centerline stations (10 for CP/M-80 version), each described by up to 30 coordinate points (10 for CP/M-80 version), may be entered for a single run. Stations must be entered in sequential order and x,y coordinate points must be entered in ascending x order. It is recommended that users first organize and record data to be entered on a supplement data entry form provided by CIVILSOFT.

Once the data have been entered for all of the stations, a screen listing of x,y values for existing and future profiles is generated for each specified station. Keyboard editing follows by specifying the station ID number and then changing, inserting, or deleting any incorrect x,y point within a station data set. The sequential nature of the program prohibits cross-sections themselves from being inserted, deleted, or later appended.

Cross-sectional plots are directed to the screen for rapidly reviewing data integrity. Plots are automatically scaled and labeled to identify the station, plot axes, and differentiate between existing and future profiles. Screen graphics can be transferred to an Epson printer under control of the DOS 2.0 GRAPHICS routine. Cross sections having higher graphic quality can also be directed to one of the same pen plotters previously listed under the CPP program description. A submenu controls lettering sizes, pen numbers used, plot scaling, and other plotting features such as station headings, a border, and scale tick marks.

Before executing the calculating sequence, program parameters are set by selecting the earthwork method to be used, setting calculation units (English or metric), specifying hard copy echoing, and changing the designated data disk drive. Once the data have been prepared, entered, and verified, calculation of earthwork quantities is a rapid process. The calculation sequence opens by having the user enter the initial earthwork quantities for the first station. Normally, the quantities would be zero for a new set of stations. If the calculations are for a continuation of stations beyond the initial 50 sta-

tions, the accumulated earthwork quantities of the last run would be entered. In this way, it is possible to calculate cut and fill volumes for an indefinite series of stations.

## EARTHWK II (CIVILSOFT) - Performance

Since so much site design is contingent upon grading and earthwork, it was important to evaluate how effectively the CIVILSOFT EARTHWK II program (mainly written for road earthwork estimation) could be used for estimating earthwork for site grading. EARTHWK II requires the user to input x,y values which define the existing and proposed elevations sampled at each station. Because of the relative complexity of trying to follow levels of topsoil stripped, topsoil replaced, varying pavement thicknesses, and "feathering" of the proposed grade back to existing grade, determining x,y values directly off the grading plan was difficult. Although requiring more time, the site was sectioned to reveal more subsurface character and allow x,y values to be determined with more accuracy and certainty. The method also provided a graphic check against erroneous values.

Descriptive x,y values, recorded on the optional data form provided by CIVILSOFT, were used to define the cross-sectional area between the levels of topsoil stripped and topsoil replaced. Using the keyboard, the x,y values were entered into the computer and double-checked for accuracy. Stepping through a station-by-station listing, incorrect x,y values were identified and later corrected through the Edit menu option. (It is important to save all data before attempting to calculate earthwork; otherwise, if a fatal error occurs and program control reverts back to the systems level, all data will be lost).

Even though preparation of the x,y data required several hours, calculation of earthwork quantities between each station was nearly instantaneous. No-cut/no-fill points can be explicitly specified within the data sets, or alternately, the program can calculate grade intersection points with negligible increases in computation time. Earthwork quantities for a sample station and the final mass ordinate table are presented in Appendix F (Tables F.1 & F.2).

Cross-section screen graphs (Appendix F, Graph F.3) for verifying the fit of inputted x,y points in representing existing and future elevations was found to be marginally useful. Automatic scaling of screen graphs occasionally result in compressed graphs in which it is hard to differentiate between existing and proposed grades. This shortcoming is not apparent when the software is used for its intended application—calculating earthwork for road design—but long horizontal distances encountered in site design forces the need for vertical exaggeration. Pen plotted graphs did not present this problem since the horizontal and vertical scales can be independently selected (Appendix F, Graph F.4).

Incremental subcut and subfill earthwork quantities calculated by EARTHWK II were very close to estimates prepared by manually planimetrying cross-sections (Table 3.2). For sections in subcut, the

computer-planimetered volume differences averaged 3.2 cy (volumes ranged from 1.6 to 656.9 cy), while differences in subfill sections averaged 2.5 cy (volumes ranged from 0 to 799.7 cy) (Graphs 3.2 & 3.3). The volume differences are likely attributable to estimating curved grade surfaces with multiple straight line segments which shave off accumulating areas (Figure 2.9). Greater accuracy can be obtained by using more x,y points to define curved surfaces. Since volumes calculated by the computer are expected to be slightly lower than planimetered estimates, higher computer estimates suggest possible errors in planimeter measurements. Smaller subcut and subfill areas found in sections near the limits of earthwork are physically more difficult to accurately planimeter and consequently introduce more latitude for error (Graphs 3.4 & 3.5). Consistently lower planimeter measurements of end area sections seem to support this postulate. Whatever the source, however, the errors effectively cancelled out. The computer calculated net subcut-subfill volume of 806.9 cy was within 99.9% of the planimetered net subcut-subfill volume of 807.4 cy.



Figure 3.9 - A convex profile curve approximated by multiple straight line segments.

To further test the computational accuracy of the EARTHWORK II program, sections of regular triangular geometry in which exact areas could be manually calculated were compared against computer estimated areas. No-cut, no-fill points were not included in each data set to force the computer to interpolate the grade intersection points. As expected, the computer area calculations were identical to manual calculations. The accuracy of the program for calculating areas bounded by curves therefore depends upon the total number of points used (the more the better), and the accuracy in estimating x and y values. Data input through a digitizer would improve accuracy in both cases.

Splining techniques could be used to graphically smooth the fit beyond the allowable 30 x,y points per station limit, but the extra mathematics and memory requirements would probably not justify slight improvements in performance. Comparison of earthwork quantities calculated by the average end and prismoidal methods revealed minute differences and prismatic subcut-subfill volumes were within 96.9% of the average end area volumes. There was no significant difference in computational speed between the two earthwork methods.

#### EARTHWORK II (CIVILSOFT) - Ease-of-Use

Of all the evaluation categories, ease-of-use is considered to be the weakest component of the EARTHWORK II program. Potential confusion can first arise when the program disk is inserted into the drive and the program name is entered. The start-up procedure is slightly

different from the CONTOUR program where the program name must be prefaced with the designation of the non-default drive (the logged drive is reserved for the data disk). To run the EARTHWORK II program, the program disk is always expected to occupy Drive A while Drive B is reserved for the data disk. Start-up for EARTHWORK II is easier than the CONTOUR program, but the inconsistency requires the user to mentally note the difference.

The menu of numbered options is easy to use and limits errant choices by eliminating the confusion of upper and lower case letters. Ease-of-use shortcomings become more evident, however, when the data must be entered and edited. Preparing data for entry is a tedious procedure because x and y distances for numerous points must be measured. Use of a tracing paper (or acetate) scaled grid overlay speeds value estimating, but mistakes can be easily made in transferring figures. If mistakes are made when typing the data, immediate corrections cannot be made once the <Return> key is pressed. It is necessary to go on and completely finish data entry because it is not possible to restart in the middle of the entry procedure.

Editing is a multi-step process. First, columnar data must be reviewed station-by-station. Instead of listing existing and future profile data together on adjacent halves of the screen, the data is separated and displayed on successive screens. Most of the time, groups of existing and future profile data are independent, but in those instances where points are shared, a side-by-side column comparison would enable the user to identify incorrect values more readily.

After scanning the multiple screen listings and identifying incorrect points, users must write down whether the point is existing or future data, the point identification number, and the station identification number. The user must then enter the edit option, proceed through the identification sequence, and finally edit the point. The editing sequence closes by requiring the user to answer whether any data is to be inserted or deleted. These options should be offered through a submenu that must be explicitly called. Corrections for a range of points cannot be handled without repeatedly entering and stepping through the editing sequence one point at a time. Finally, it is hard for the user to develop a consistent answering rhythm. Some answers to input prompts are immediately executed and others require a <Return> which forces users to constantly watch the screen.

In short, inputting cross-sectional data through the keyboard is a tedious, time-consuming, and error-prone process. Editing was found to be much easier through the use of a word processor in which lists of points can be scrolled up and down, and full screen editing allows immediate corrections. Ease-of-use will be vastly improved after CIVILSOFT completes development of Option 3 which allows data input through a digitizer. Other improvements could be made through resident program full-screen input and editing, and through multi-windowing.

## EARTHWK II (CIVILSOFT) - Error Handling

To test error handling procedures, nonvalid responses were typed for every prompt or menu offering. In all cases, nonvalid responses were locked out. When attempts were made to enter new cross-sectional data with former data residing in active memory, the program stated this condition and waited for a positive confirmation before clearing the memory for new data. Double confirmation is also required before overwriting any data file. One major flaw was discovered when responding with any other keystroke besides a "y" to this prompt. Non "y" responses caused the prompt to repeat itself indefinitely until the computer was reset and all data was lost. If users do not want to overwrite an existing file, they should be able to save the data under a different file name.

When describing a vertical grade change such as a curb edge or retaining wall, it was found that no two x values could be exactly the same. One value had to be slightly offset from the other, for example 37.0 and 37.01. Failure to do so caused a fatal division by zero error when the linear interpolation routine using slope  $(\Delta y / \Delta x)$  was executed.

## EARTHWK II (CIVILSOFT) - Documentation

Program documentation provided by CIVILSOFT consists of a full-size (8 1/2" x 11") three-ring notebook in which updated materials can be added as they are made available by the company. Pages interspersed with sample-run results are logically ordered, but no sectional dividers are included. No index is provided, but considering only twenty-two pages of actual instructions for program operation (excluding multiple appendices), most needed information can be found by just flipping through the manual. Boldface type or more topic underlining, however, would greatly augment visual scanning.

Documentation is divided into three sections: 1) "Introduction", 2) "Using the Program", and 3) "Appendices". The Introduction gives a succinct summary of program features and describes how data must be prepared prior to entry. The "Using the Program" section shows menu facsimiles and describes the function and operation of all menu choices. The section of appendices provides examples of earthwork results, general program equations, procedures for getting started, operational hints, error messages, and hardware requirements. The operational hints are especially helpful, but they should also be placed within relevant text sections instead of being relegated to a single page where they can be missed amongst pages of sample program output.

The writing style describing program operation is not superfluous and generally communicates needed information quickly. The "Getting Started" appendix could use some improvement. The pseudoconversation: "Next -- turn the computer on. So far this has been relatively painless, hasn't it? Let's press on then." hardly seems appropriate for the typical engineer-user. Perhaps engineers would not be reading this section in the first place.

All CIVILSOFT products are maintained by a full-time staff of professional engineers and programmers. Program updates are stated to be available for a charge of \$25 to \$50 which covers the cost of processing, handling, and a new manual if needed.

#### EARTHWK II (CIVILSOFT) - Application to Landscape Architecture

Earthwork estimation is a necessary, but time-consuming part of landform design documentation. Most landscape architectural firms, especially those organized as design-build, could reduce their amount of time devoted to computing earthwork by using this program. Time reductions associated with preparing data will not be as apparent since the process is comparable to manually measuring cross-sectional areas with a planimeter. Even so, the cost of this program could be recovered rather quickly if earthwork estimations are routinely performed. It is a useful stand-alone program, but cannot be considered a highly interactive design tool as discussed more fully in Chapter 4.



## MFE ASSOCIATES, INC.

MFE Associates is a firm composed primarily of landscape architects who offer consulting services in computer applications which require office analysis, computer purchase, installation and training assistance. In addition, MFE Associates has developed and is marketing site engineering and office management microcomputer software. The software is adapted to most Apple and IBM microcomputer hardware systems.

### EARTHWORKS II

EARTHWORKS II is a series of programs which calculate cut and fill earthwork volumes based on the average end area method. Data points for forty-five cross-sections of up to 50 points each are manually entered into the computer through the keyboard. Incremental earthwork volumes derived from cut and fill areas are then calculated between each pair of stations, followed by a summary table for all the stations. Additionally, program options are provided for screen graphing of contour plans and sections revealing existing and proposed grades.

#### EARTHWORKS II (MFE) - Description and Operation

Like most engineering type software, EARTHWORKS II is a menu driven program in which choices are specified by number. Like the CIVILSOFT earthwork program, existing and proposed grade elevations are defined by coordinate points entered into the computer through the keyboard. The first datum figure is the distance measured along the section line from an established baseline to the sampled point. The second figure represents the point elevation. Instead of ending the section prompts with a special character like "s", the user must specify the number of sections and points to be entered. For a single run, the program is written to accept 40 stations of up to 50 points each. Existing and proposed elevations are entered in a separate input sequence and are stored in different files.

Sectional data can be reviewed through a screen or line printer listing. Editing procedures are available after entering data for each station, or editing can be done later through menu Option 2. Data points can be inserted or deleted, as well as entire stations if they are located between the first and last empty sections.

Cross-sectional data can be graphically reviewed through a sub-menu option which plots each cross section on the screen. Another option allows screen plotting of plan view contour lines connecting all non-decimal elevation values within the sectional data sets. Spot elevations are indicated by "+" marks, but no contour numbering is displayed. Section lines are indicated by tick marks along the top and bottom of the screen (see Appendix G for a sample contour plot). All screen graphics can be dumped to a line printer using the <PrtSc> key if the DOS GRAPHICS routine has been previously loaded. No pen plotters are supported by the program.

Incremental earthwork volumes are based upon the average end area method in which cut and fill areas are calculated through the polygonal area technique. It is unnecessary to manually or graphically determine no-cut/no-fill points since the program can mathematically calculate them. The calculation sequence ends by the generation of a summary earthwork table in which volumes can be expressed in either English or metric units (see Appendix G for sample data output).

## EARTHWORKS II (MFE) - Performance

To enable a performance comparison to the CIVILSOFT earthwork program, the same Timbercreek II site information was used in evaluating MFE's earthwork program. Program documentation states that it is unnecessary to draw cross sections to derive topographic data. Distance measurements and elevations taken directly off the plan are suitable for generalized earthwork estimates. Earthwork quantities were calculated using this baseline method, along with more accurate estimates obtained by drawing cross-sections and entering x,y coordinates as described below.

Data for detailed estimates of subcut and subfill quantities can only be accurately determined through drawn cross-sections. Cross-sections also increase accuracy by enabling more intermediate x,y points between whole number contours to be more precisely estimated. For each of the 17 cross-sections, data were entered through the keyboard. Unlike the CIVILSOFT program, existing and proposed topographic data are stored in separate files. Some inconvenience is posed because existing and proposed data cannot be listed side-by-side for comparison, but positively, separate files allow different proposed grading alternatives to be combined with existing data that only need to be inputted once.

Once the existing and proposed data were manually entered for the 17 cross-sections, incremental subcut and subfill volumes for a maximum of 16 proposed data points per station were performed in under five seconds --only slightly longer than CIVILSOFT's program written in assembly language. Since both programs use the polygonal method of calculating areas, the earthwork calculations were identical as expected. The computer-calculated net subcut/subfill volume of 806.9 cy was within 99.9% of the planimetered net volume of 807.4 cy (Table 3.2).

Calculated output could also be improved by displaying more intermediate results. Incremental subcut and subfill volumes are not displayed until the summary table is generated after stepping through the contributing cross-sections (Appendix G, Table G.3). The earthwork summary should also list subcut and subfill areas in addition to earthwork volumes. A running total of subcut and subfill volumes would also be useful for planning excavation circulation, or for phasing the grading of large sites.

One option generates plan view contours for the purpose of roughly checking the accuracy of numeric data entered for subcut and subfill calculations. Since data is processed and plotted section-by-

section, the usefulness of the contour plan is highly variable and depends upon the nature of the contours. In the case of the Timbercreek II site, the contour plan was highly distorted at the southwest corner of the site where the contours ran more parallel to the section lines (Appendix G, Graph G.1). Program documentation describes instances where contour lines looping back and forth across sections may be interpreted as zig-zag lines (Figure 3.10). Nonlooping contours of this site should not have posed distorting conditions, yet the plot exhibited discontinuities and many lines appeared to be erroneous. Further distortions were introduced when the contour plan was automatically scaled to fit the rectangular screen. Nonuniform distances between sections were also scaled as being equal. The contour mapping option is not intended to produce accurate plots, and in this instance, portions of the contour plan were nearly unintelligible.

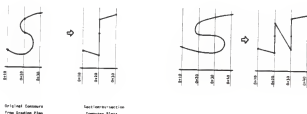


Figure 3.10 - Conditions causing erroneous contour plots using the MFE EARTHWORKS II program.

By contrast, the cross sectional plots were extremely useful in verifying the accuracy of inputted elevations (Appendix G, Graph G.2). No labeling is provided to distinguish contours, but existing contours are represented as dashed lines and proposed contours as solid lines. This technique is fairly effective except when aliasing of diagonal lines gives solid lines a jagged, disruptive appearance. The most useful graphing feature is selectable vertical exaggeration. Another useful feature is the inclusion of no-cut/no-fill locations and associated numeric values. The most significant shortcoming of cross-sectional plotting is the omission of labeling along the elevational axis.

#### EARTHWORKS II (MFE) - Ease-of-Use

Numbered menu choices which do not require a <Return> make the program easy to use by eliminating the need to remember and type command words. Yes-no choices are set up through defaults which

enables the user to quickly step through the program without accidentally following irreversible steps. All important operations like overwriting files and exiting the program require an explicit, non-default response. Returning to the main menu from any menu level or option is possible through the <Esc> key.

Entering data through the keyboard is a tedious and time consuming process. Like the CIVILSOFT program, it is easier to first write down the topographic data on a summary form so it can be systematically entered into the computer with fewer mistakes. Before data can be accepted for any cross-section, it is first necessary to specify the number of points to be entered. To avoid complications resulting from miscounting points or mistyping the specifier number, the data input sequence should be programmed as a continuous loop that is exited by typing a termination character like "a".

According to program documentation, the proper creation of files requires data entries to be separated with commas. Inserting commas greatly slows down entering data through the numeric keypad. It was found, however, that pressing the <Return> key instead of the comma key inserts commas in the appropriate places and earthwork calculations are performed without flaws.

Editing is fairly easy to perform when entering data. Opportunity is provided for making corrections at the end of entering data for each section before proceeding to the next section. Editing data at a later time is less convenient. Identifying incorrect values is the first step in editing. The algorithm which calculates subcut and subfill areas requires the beginning and ending points of the existing and proposed grades to exactly match. Not being able to list existing and proposed elevations adjacently prevents direct comparisons, although the program does identify the section in violation. Once the incorrect point is identified, the editing sequence steps through the data one point at a time. If the value is correct, the user presses the <Return> key and continues on to the next point; otherwise, the replacement correction is typed. For small sections this step-by-step process activated by the <Return> key is convenient. But for sections having numerous points, provisions should be available to circumvent the stepwise procedure by explicitly typing the point number to be corrected.

## EARTHWORKS II (MFE) - Error Handling

Error handling procedures for the EARTHWORK II program were judged to be very good. When the main menu appeared, all keys (including <Ctrl Break>) were inactivated except numbered keys necessary for menu choices and the <Alt-Ctrl-Del> sequence for resetting the computer. No matter what program operation sequence was followed, it was always possible to return back to the main menu by pressing the <esc> key.

A menu option which often induces the user to error in many programs is loading a file. In the EARTHWORK II program, selection of

this option opened by having the user type the file name (without extension) to be loaded. Choosing the default, a file directory was printed on the screen. When the files were reviewed and the file name was entered, typing overwrote the default word "directory". Before the file was retrieved, the program automatically truncated any remaining letters of the default word that were not overwritten by the short file name. When the "load" option was selected without a disk residing in Drive B, ERR #71 was displayed, but since it was nonfatal, it was possible to try again by returning to the main menu by pressing the <esc> key. The program could be improved at this point by describing the error and recovery operation rather than just displaying the BASIC error code.

All of the remaining menu options that were tried incorporated error handling procedures which sounded an alert when invalid responses were given or incorrect operations were attempted. In all cases, error recovery was possible. Whenever disk accesses required clearing the memory, opportunity was given to first save current data on the disk. A protective default of "y" required deliberately typing "n" before disk access was permitted.

The only inadequate error handling procedure that was found existed in the three questions concerning output in the "calculation of earthwork" option. If a number was typed instead of a "y" or "n", the answer was always interpreted as a "y". No harm was done and it was possible to make the correct choices by pressing the <esc> key to return to the main menu and then re-enter the menu option.

## EARTHWSK II (MFE) - Documentation

Program documentation consists of a three-ring notebook containing photocopies of typed pages. Organization is outlined through a Table of Contents listing the major sections: Introduction/Terminology, Getting Started, Tutorial, The Menu, and four appendices (errors, set units, technical references, and sample data sets). MFE provides a tabbed divider for separating earthwork program documentation from other documentation that may be added later. Superficial changes that would improve formatting include subsection dividers, boldface type for topic headings, and compilation of an index. Professional appearance is also downgraded through poor quality hand sketches and numerous typographical errors.

The first half of the manual is written as a tutorial while the latter half is devoted to describing the eight menu options in greater detail. Content of the tutorial, as well as the remaining portions of the manual, is complete and program operation is clearly explained. Reading is slow, though, because of the text formatting. Screen prompts are intermixed with paragraph descriptions which make visual scanning for later referencing more difficult. The documentation would be easier to follow if general information was first described, and then step-by-step procedures were formatted in two columns. The

first column would contain screen prompt labels and the right column would be reserved for associated comments or instructions. If this format is impractical, two-color printing would enhance clarity.

Software support can be obtained by calling or writing MFE Associates. Answers to calls may not be returned the same day since an electronic answering service is used instead of a full-time receptionist.

#### EARTHWORKS II (MFE) - Application to Landscape Architecture

The MFE earthwork program is a low-cost, time-saving program for calculating earthwork based on the average end area method. Accuracy depends upon the number of x,y coordinate points defining the existing and proposed grades that the user is willing to enter. Use of the program is confined, however, as a post-design tool for estimating earthwork, rather than an interactive graphic modeling system enabling grading plans to be prepared and refined through immediate known quantities of associated earthwork.

Table 3.2

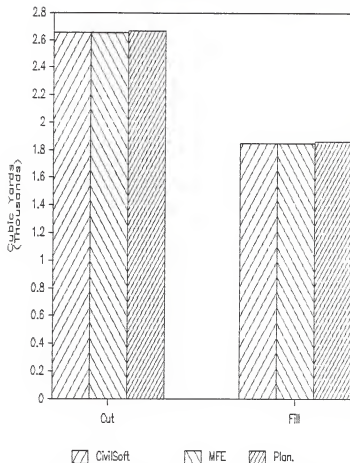
Tribercreek II  
Manhattan, Kansas

EARTHWORK COMPARISON - Subcut and Subfill Quantities  
(All earthwork volumes are in cubic yards)

Station	CIVILSOFT				NFE Associates				Planimetered	
	Subcut	%	Subfill	%	Subcut	%	Subfill	%	Subcut	Subfill
0										
0 + 31	3.3	61.8%	0.0	0.0%	3.3	61.8%	0.0	0.0%	8.6	0.0
0 + 39	14.4	5.8%	0.0	0.0%	14.4	5.8%	0.0	0.0%	15.3	0.0
0 + 81	340.2	-1.5%	0.0	0.0%	340.2	-1.5%	0.0	0.0%	335.3	0.0
	656.9	-0.2%	6.0	24.1%	656.9	-0.2%	6.0	24.1%	655.6	7.9
1 + 37	396.0	1.0%	5.4	25.0%	396.0	1.0%	5.4	25.0%	409.0	7.2
1 + 88	141.7	2.2%	6.1	-21.3%	141.7	2.2%	6.1	-21.3%	144.9	5.0
2 + 22	184.6	1.8%	95.3	4.4%	184.6	1.8%	95.3	4.4%	188.0	99.7
2 + 82	88.0	0.2%	33.6	6.3%	88.0	0.2%	33.6	6.3%	88.2	35.8
2 + 99	326.1	0.7%	79.1	7.8%	326.1	0.7%	79.1	7.8%	328.5	85.8
3 + 53	194.2	3.1%	238.3	1.7%	194.2	3.1%	238.3	1.7%	200.5	242.4
4 + 09	41.7	8.9%	119.1	0.7%	41.7	8.9%	119.1	0.7%	45.8	120.0
4 + 26	198.6	1.4%	799.7	.0%	198.6	1.4%	799.7	.0%	201.5	799.4
5 + 16	30.4	-11.3%	207.2	-0.4%	30.4	-11.3%	207.2	-0.4%	27.3	206.3
5 + 37	29.8	-20.9%	246.4	-1.5%	29.8	-20.9%	246.4	-1.5%	24.6	242.8
5 + 85	5.7	-109.6%	10.0	-27.9%	5.7	-109.6%	10.0	-27.9%	2.7	7.8
6 + 05	1.6	-125.4%	0.0	0.0%	1.6	-125.4%	0.0	0.0%	0.7	0.0
6 + 20										
Total	2653.2	0.5%	1846.2	0.7%	2653.2	0.5%	1846.2	0.7%	2667.4	1860.1
Net Balance	807.0	0.04%			807.0	0.04%			807.4	

Notes: % = Percentage difference compared to planimetered estimate

# EARTHWORK COMPARISON CHART

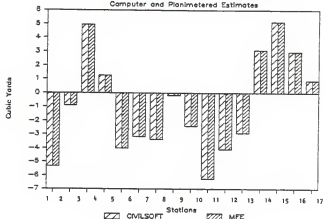


Graph 3.1 - Subcut and subfill quantities calculated by the CIVILSOFT and MFE programs based on the average end area method of drawn cross-sections are compared to estimates derived through manually planimetered cross-sections. Accuracy is high because drawn cross-sections enabled x,y coordinates to be specified at "critical" locations of grade changes.



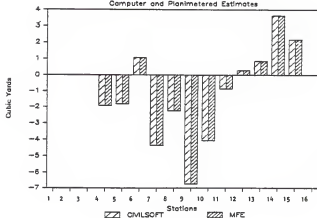
# CUT VOLUME DIFFERENCES

Computer and Planimeted Estimates



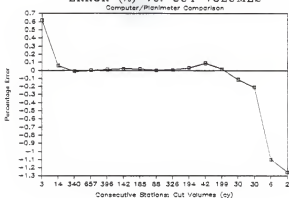
# FILL VOLUME DIFFERENCES

Computer and Planimeted Estimates

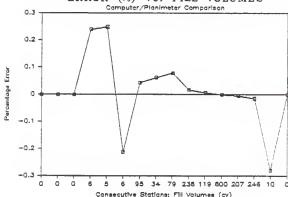


Graphs 3.2 & 3.3 - Subcut and subfill volume differences (cy) between computer and planimeted estimates randomly varied between consecutive stations and reflect both positive and negative differences.

# ERROR (%) vs. CUT VOLUMES



# ERROR (%) vs. FILL VOLUMES



Graphs 3.4 & 3.5 - Subcut and subfill quantities calculated by the CIVILSOFT and MFE earthwork programs are compared to planimetered estimates and are expressed as a percentage error where  $\% \text{ error} = 100 - \text{computer estimate} / \text{planimetered estimate}$ . Accuracy decreases at the feathered edges of grading where earthwork volume errors are more significant when compared to smaller incremental earthwork quantities.

## PACSOFT, INC.

PacSoft, an independent software company based in Kirkland, Washington, offers microcomputer software in the application areas of digital terrain modeling, surveying, and storm water hydrology. Unlike many software companies which offer stand-alone programs, most of PacSoft's software is integrated in which topographic or engineering data can be passed and shared between programs. All of the software is written for Hewlett Packard hardware including HP Series 80, Series 200, HP9845, HP9000, or Series 500 computer systems.

### TOPOGRAPHY Digital Terrain Modeling Software

Although most of the software offered by PacSoft is useful to landscape architects to some degree, this review concentrated on the Digital Terrain Modeling (DTM) software. Narrowing the scope even more for generalized software comparisons between companies, the PacSoft DTM modules for data input, contouring, three-dimensional projections, and earthwork computations were examined most closely. The remaining modules were also tested, and many of the results are included for demonstrating the DTM system capabilities, but detailed descriptions are omitted.

The Digital Terrain Modeling software developed by PacSoft is based on a rectangular grid system. Modeling is performed by building a data base using the COORDS, GRID I, and GRID II data input programs, and then pursuing an application through numerous other program options purchased separately or in groups (Appendix H). Much more modeling power is utilized if several different programs are used together.

Selecting the optimum grid cell size is the single most important decision made during terrain modeling. Grid cell sizes which are too large will fail to capture sufficient topographic detail, while cell sizes which are too small may become redundant, waste memory space, and prolong computation time. Program documentation states that the following points should be considered when selecting the cell size (p.6-4):

- 1) The cell size should be equal to approximately half the average distance between data points for most projects with randomly distributed data;
- 2) The cell size should be no less than the shortest distance between two data points;
- 3) Very uneven data point distribution requires a smaller cell size;
- 4) Some features cannot be represented by a grid. The limit of one elevation value per location prevents definition of vertical surfaces and overhangs. This is a problem inherent of all grid models. Better results may be obtained by reducing the cell size; and

- 5) If two different grids are being compared for volume computations, the cell sizes must match.

Program documentation also suggests that a site having both uneven and smooth surface areas may be divided into multiple files corresponding to different grid sizes. Uneven areas can be depicted through a tight grid of small cell sizes, while smoother areas can be represented with fewer elevation points of a looser grid having larger cell sizes. Up to 1000 elevation points can be actively processed by TOPOGRAPHY programs accessing a flexible disk holding somewhat less than 16,000 grid points.

## TOPOGRAPHY (PacSoft) - System Descriptions

### Building a Topographic Base

Entering digital terrain data is accomplished by using one of four available input programs: COORDS, GRID I, GRID II, or option 4 of the EDIT program.

COORDS. The COORDS program creates a coordinate file of random points specified by northing (y), easting (x), and elevational (z) values. Point values may define topographical surfaces or any spatially related x,y,z information. Once points have been entered, they can optionally be rotated, translated, or scaled to different values. Coordinate data can also be generated and transferred from the PacSoft ESP-200 Surveying software, HP/Wild 38042 Surveying software, or any compatible surveying software offered by other companies. A COORD program option will then allow elevations to be appended to each transferred point. Besides allowing entry of random topographic points, the COORDS program is also used to build a coordinate file for two-dimensional drawings used in the 3-D PLAT program.

GRID I and GRID II programs convert randomly distributed x,y,z coordinate data into a grid format usable by the rest of the TOPOGRAPHY programs. Both programs establish a gridded terrain surface in which elevations at each grid intersection are interpolated from the random coordinates entered through the COORDS program. Grid elevations are stored in a TOPO file.

Grid I. This program is used to convert random coordinate data into a grid format in which elevations at each grid intersection are independently interpolated. Grid values are determined by an enclosing plane formed by the three closest random points. Interpolation is performed in a multi-pass search, ranging from 4 to 10 selectable passes, which starts with the three closest points and progressively works outward to farther points which may form an enclosing triangle. For example, a search limit of 5 means that all combinations of 3 of the 5 closest points will be analyzed (the larger the number, the longer the separation distance between the random point and grid point). Obviously, more passes will slow down the search process.

Table 3.3 - Three point combinations analyzed for a pass limit of 5.

Three Point Combination	Combined Distance	Grid Sketch
1-2-3	6	
1-2-4	7	
1-3-4	8	
1-2-5	8	
1-3-5	9	
1-4-5	10	

If no enclosing triangle is found after trying all the triplet combinations, the program will extrapolate rather than interpolate to generate the grid elevation (Figure 3.11). This condition most frequently occurs along the edge of the grid where all the data points are to one side. Additionally, a value called a reliability index is assigned to each grid point. The value ranges from 1 to 100 and indicates relative accuracy of the interpolated points based upon the point separation distances and the evenness of random point distribution. A lower reliability index corresponds to a computed elevation of less accuracy.

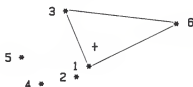


Fig. 3.11 - The grid point represented by the (+) lies outside the triangulated range of the first five closest random points and will have a lower reliability index due to extrapolation. If the search range is expanded to include the sixth point, interpolation is possible (PacSoft TOPOGRAPHY Documentation, p.6-5).

**GRID II.** Operation of the GRID II program is very similar to GRID I except no extrapolation is performed and the elevation is left unsigned ( $z = 0$ ) when a pass fails to find an enclosing triangle. All assignable grid values in GRID II therefore have a reliability index of 100.

Unlike GRID I which automatically makes additional passes through the point data until the user-selected pass limit is reached, GRID II pauses after each pass for the user to decide whether or not to continue. During the operation of each pass, the user can monitor grid construction as plus (+) signs appear on the screen when point

elevations are interpolated. In this way, the user can see where "holes" still exist and decide whether another pass will be worthwhile. On color monitors, the plus signs can be color coded to correspond to different passes. A maximum of eight passes is possible.

D-MODEL (Digitized Modeling). A digitizing plotter or graphics tablet is used in this option to convert existing contour maps into a grid formatted TOPO file for use by the 3-D projection, earthwork volume, and cross-section options. The D-MODEL option is capable of creating new TOPO files from scratch or editing existing files. Data are entered by overlaying a grid on the existing contour map, tracing along grid lines, and digitizing each time a contour is crossed. The HP 9111, HP 9874, CalComp 9000, and Numonics 2300 digitizers are supported.

#### SITE ANALYSIS

SLOPE (Slope Shading). The SLOPE program shades the steepness of a surface according to a user selected range of slopes (20 slopes maximum). Shading uses various patterns, line spacing, pen sizes, and colors. When the slope shading map is completed, a summary is printed stating the total area in each slope category.

VECTOR (Site Drainage). The VECTOR program plots a plan view map showing arrows pointing downhill in the directions that surface water will flow.

#### CONTOUR MAPPING

Two programs are available for plotting rough or smooth contour lines interpolated through a grid of z values which may represent elevations, density, or any other third dimension. The degree of contour rounding is dependent upon which of the two programs is used.

ROUGH (Rough Contouring). This option generates a plan view map in which contours are interpolated and plotted through grid cell values read from a TOPO file. Contours have an angular appearance because of straight line point-to-point connections. The main advantage of the program is its plotting speed.

SMOOTH (Smooth Contouring). The SMOOTH program is similar to the ROUGH contouring program, except that contours are plotted more slowly with greater graphic quality. When using the SMOOTH option, the user has the choice of specifying the minimum reliability index to limit contour plotting based on less accurate elevations. Original, random points can also be superimposed on the contour map by using the Plot Points option of the COORDS program.

Preparing base maps can be greatly augmented through a program function which enables reverse plotting on the back of transparent sheets (Figure 3.12). This function is only available for reflecting contours through one or both axes, so reference grid or axes labeling remains unreversed.

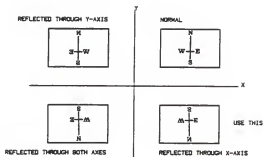


Figure 3.12 - Examples of contour plotting orientation (SMOOTH CONT).

### THREE-DIMENSIONAL PROJECTIONS

Landscape architects and other users of contour maps have learned to visualize in three dimensions when viewing flat, two-dimensional representations of topography. These programs greatly extend these mental visualization abilities by producing tangible three-dimensional plots of landform.

**3-D GRID.** This option uses an existing or proposed TOPO file to plot a three-dimensional "fishnet" grid of landform. Even though the view is an orthographic projection rather than a true perspective, the user can easily perceive a bird's eye view of topography from any direction and inclination height. The user has additional options of drawing an enclosing box, labeling contours along the vertical axis, selecting the contour interval, and re-scaling the plot to adjust the view or vertical exaggeration. The 3-D plots are used as the topographic base for the 3-D PLAT option.

**3-D CONT (3-D Contouring).** Using a TOPO file, this option plots a three-dimensional stacked contour plot which can be viewed from any rotation or tilt angle. Landscape architects will be able to easily visualize three-dimensional contour plots since they are accustomed to reading two-dimensional maps which represent topography through contours.

3-D Plat. This program overlays any two-dimensional drawing onto a three-dimensional surface. Applications include analyzing three-dimensional plots of a subdivision plat map, building or reservoir footprints, and well and test boring locations. A utility routine is also included for transferring 2D plat data from the 38042 F Surveying Volume F (drafting) program.

## SITE SECTIONING

PROFILE and XSECT (Cross Section). The PROFILE program computes and plots an elevational profile along a plan view baseline which may include both straight and curved segments (for example, a road center-line). Plots can be drawn on pre-printed plan/profile sheets or the program can plot a labeled profile grid. The XSECT program computes and plots cross sections at any width and interval along a baseline (can be the same one as used in PROFILE). Cross sections are plotted either perpendicularly or radially to the baseline. Two or more sections may be superimposed on one plot to compare different surfaces.



Figure 3.13 - Example of a road shown in plan depicting the orientation of sections generated by PROFILE and XSECT.

## EARTHWORK VOLUME CALCULATIONS

Whenever landscape architects manipulate a landform surface, estimations of associated earthwork is a prime consideration. Earthwork volumes between any two surfaces can be calculated using either the EW PRNT or EW PLOT programs. These programs are highly desirable in site modeling and should therefore be included in any assembled package of TOPOGRAPHY programs.

Because terrain surfaces are represented through a grid, earthwork calculations are based on the truncated prism method. Grid cells are divided into triangles and the resultant prism volumes are calculated through the formula:

$$V = A/3 * (H1 + H2 + H3) \quad \text{where } V = \text{volume}$$

$$A = \text{area of base}$$

$$H = \text{height of sides}$$



The original surface must be defined in a TOPO file, and the proposed surface may be another TOPO file, a horizontal plane (analogous to a reservoir water level), or an inclined plane determined by three points. When comparing two grids, the proposed surface can be adjusted up and down to find the most economical earthwork balance.

When preparing the surface grids, it is imperative that the cell sizes are identical. It is not necessary, however, for the grid boundaries to coincide since volumes will only be calculated for overlapping areas. In this way, small areas can be regraded without having to enter remaining elevations of unaffected, existing points. Another feature allows swell and shrinkage factors to be applied to cut and fill volumes.

EW PRNT and EW PLOT (Earthwork Print and Plot). Both of these programs calculate total cut and fill earthwork volumes, surface areas, cut and fill depths, and earthwork volumes within each grid cell. Results are listed on the line printer when using the EW PRNT program. The EW PLOT program uses a pen plotter to plot calculated quantities on a gridded map. Plotting also enables the line of intersection (daylight line) between two surfaces to be depicted. Both programs are useful for analyzing site grading, mines, reservoirs, and landfills.

#### MODEL MANIPULATION / UTILITY PROGRAMS

I-MODEL (Interactive Modeling). The interactive modeling option is one of the most powerful programs in the TOPOGRAPHY system. It is designed to allow the operator to interactively build an entire surface from the keyboard, or adjust small surface areas within TOPO files already created. SEARCH and REPLACE functions selectively work on points having elevations or reliability indices less than a defined maximum.

XLINK (Data Transfer/Other Earthwork Systems). This option links the TOPOGRAPHY cross-section program with HP 38042 Volume H Earthwork software employing the average-end area method for calculating earthwork. Because cross-sections are calculated automatically, there is no need to enter pairs of point numbers defining existing and proposed surfaces. Sections can be any width and can fall anywhere within the boundary of the modeled terrain.

#### TOPOGRAPHY (PACSOFT) - Performance and Ease-of Use

STDS (System Standards). Performance testing began by building a topographic data base representing the pre-development site conditions of Timbercreek II. The first module invoked was STDS in which the addresses for the hardware peripherals were entered. Use of a separate module to adapt the TOPOGRAPHY system to a particular hardware set-up and control system-wide formatting like fixing displayed decimals is most convenient. System addresses and formatting specifica-

tions are automatically retrieved from the disk whenever the system boots, and will be retained indefinitely until deliberately changed. Once set, no subsequent system standards were changed during the evaluation, except for redirecting data listings to the screen or Thinkjet printer.

COORDS. Existing topographic data for the site were available in a grid format, but data were entered as "random" coordinates to test the input procedure of the COORDS program. Each coordinate entry consisted of a point number, northing (y), easting (x), and elevation (z). Mistakes were corrected by specifying the same point number for the next entry prompt, and then retyping the northing, easting, and elevational values. Data entry could have been more rapid if the computer automatically generated successive point numbers, only requiring the user to enter the northings, eastings, and elevations. Immediate editing could still be retained by providing an edit function key to halt automatic point numbering, which could later be reactivated. One reassuring feature of the program, particularly when building large data bases, was the automatic and frequent saving of data to the disk. Although not used, the ROTATE, TRANSLATE, and SCALE menu options are powerful functions to convert or correct entire data bases.

GRID I. The "random" coordinate data were then converted to a TOPO file using the GRID I program to sort the points in descending northing order. Next, a grid cell size of 30'x 30' was selected. Setting up the execution parameters ended when the pass search limit was set at eight. The program was then left unattended for several hours while 498 grid elevations were interpolated and extrapolated.

Because the program is intended to be a processing utility program requiring very little interaction with the user, it was very easy to use. In routine landscape architectural practice, most users will find it convenient to set high search pass limits and let the program run unattended overnight for large data files.

GRID II. A second TOPO file was created from the coordinate data using the GRID II program. Like GRID I, the same grid cell size of 30'x 30' was used for GRID II. Processing was accomplished in a multi-pass sequence in which points were plotted on the screen as they were solved. Six passes, each requiring 20 to 25 minutes to execute, were made through the 498 points. Compared to GRID I, GRID II requires more user interaction, but more processing control is enabled since intermediate decisions must be made whether to execute another pass. Since extrapolations are not performed, many grid "holes" remained. For the TOPOGRAPHY programs to yield complete graphic earthwork calculation results, it would be necessary to use the D-MODEL or I-MODEL programs to input values for unsolved points.

3-D GRID. After the TOPO file was created, a topography plot was made using the 3-D GRID program. Of all the graphics programs within the TOPOGRAPHY system, 3-D GRID proved to be one of the most flexible and visually effective. Three-dimensional grid plotting is much more rapid than either the ROUGH or SMOOTH contour programs, so 3-D GRID provides a good method to visually identify and locate anomalous topographic data. Several abnormal spiked projections and depressions

were present in the first three-dimensional grid plotted. Exact locations of erroneous data points were easily found by counting grid lines and making corrections using the EDIT program.

The three-dimensional grid program provides no hidden line removal. Some trial-and-error experimenting is therefore necessary to find the most satisfactory view rotation, tilt angle, and vertical exaggeration. The documentation suggests that it is usually best to first plot the reference box when trying to determine the optimum view orientation. General view angles can easily be mentally visualized, however, so more revealing surface plots were still found to be necessary. For the Timbercreek II site, a rotation angle of 320 degrees, a tilt angle of 20 degrees, and 5:1 vertical exaggeration was found to be most visually satisfactory (Appendix H, Graph H.6). Since it is hard to remember the view orientations for plot trials, the program could be improved by plotting the TOPO file name and plot specifications (rotation, tilt, and vertical exaggeration) with each graphic landform view.

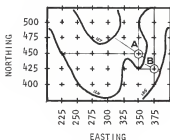
Plotting was rapid and efficient because the pen only raised and repositioned at the end of each grid line. Grid lines were somewhat spotty, though, because of ink absorption each time the pen momentarily hesitated to calculate the next pen movement. Although not visually degrading, the problem could probably be eliminated if a different type of plotter paper was used; perhaps marker paper with a backside plastic coating. To be an interactive design tool, the program could also be much improved if the landform image could be generated on the screen so topographic manipulations could be immediately viewed.

D-MODEL. After viewing the 3-D grid plot, a decision was made to rebuild the topographic base with a slightly tighter grid spacing of 25' x 25' (756 points) to capture slightly more representative detail, particularly around the satellite dish located at the southeast area of the site. It is possible to splice grid sections having different cell resolutions together, but the technique was considered troublesome since additional procedures would need to be followed when using each of the remaining programs. Building a new data base could also have been accomplished through the EDIT program which automatically generates northing and easting values based upon grid rows and columns in which the user only needs to enter elevations. Prior work with this program demonstrated its speed and ease-of-use, and it is highly recommended as a method for building data bases when topographic information is available in a grid format. One posed disadvantage is that additional random data further describing irregular topographic features cannot be entered.

The D-MODEL program was chosen as the method for rebuilding the topography base for two reasons. Foremost, a 24" x 36" contour map of existing site conditions was available for eventual digitizing, precluding the need to interpolate and assign spot elevations to hundreds of grid points. Another reason was to maintain format consistency when the digitizer would be used to enter proposed grading.

Digitizing was performed by making an 8"x 10" PMT reduction that would fit upon the HP9111A Graphics Tablet. In practical applications, routine use of the D-MODEL program would require a larger digitizer that could accommodate a standard 24"x 36" or larger document. Digitizing along bidirectional grid lines of the reduced contour sheet took a little over half an hour. Time spent digitizing will depend upon the number of crossed contours and how often the input sequence must be switched between positive and negative slopes. When mistakes were made, they were easily corrected by redigitizing the line and overlaying elevational values.

In most instances, elevations interpolated through D-MODEL were very close to numerous spot checks that were performed. The best results seemed to be obtained when the contours ran at a forty-five degree angle to the grid. D-MODEL cannot make interpretive judgments of unusual conditions as illustrated in Figure 3.14. Depending on the end application, accuracy can be improved by reviewing the generated results and manually editing those elevations in unusual topographic areas which deceived the program.



E-W Interpolated Elevation	N-S Interpolated Elevation	Bidirectional Interp. Elevation	Diagonal Interp. Elevation	PacSoft D-Model
126.00	126.00	126.00	126.19	126.00
125.27	125.20	125.24	126.33	125.20

Figure 3.14 - Grid intersection points A (N450, E350) and B (N425, E375) illustrate two deceiving conditions which decrease the accuracy of the D-Model elevational interpolation routine. The N-S and E-W lines of point A cross the same contour which doubles back on itself and results in point A having the same elevation as the contour which surrounds it. The second deceiving condition depicted by point B is caused by disproportionate northing or easting distances between contour crossings. The resulting average elevation obtained from bidirectional interpolation is skewed away from the more accurate elevation obtained by interpolation along a diagonal line which crosses the contours at right angles.

D-MODEL does offer several advantages over other input techniques. The most significant advantage is that many typographical and transcription errors are avoided when working with hundreds of points. The data base can also be rapidly built because the TOPO file is compiled as information is digitized. There is no need to spend time converting a coordinate file into a TOPO file through GRID I or GRID II. As a protection against losing large blocks of data, grid coordinates and elevations are automatically and frequently written to the disk.

Overall, the program was easy to use and a screen indicator showed the number of the next contour to be digitized. Although processing might be slower and more complex, one ease-of-use improvement would be allowing the user to continuously follow single contours, digitizing at strategic intervals, instead of digitizing along grid lines which cut across contours.

ROUGH and SMOOTH CONT. After the 3-D GRID program was used to quickly identify incorrect elevations, a plan view contour map was generated by ROUGH CONT (Appendix H, Graphs H.1 and H.2). Overlaying the plotted contour map on the PMT reduction of the existing contour map revealed few discrepancies. As expected, the berm and depression around the satellite dish and several small swales were not accurately captured because of noncoincidence with grid intersection points. PacSoft is currently developing a T-NET program upgrade based on a triangulated irregular network that will better capture small details such as streams, vertical walls, and abrupt grade changes. The grid model will be retained, however, because of its processing speed to work in concert with the T-NET model.

The only drawback of the program was the way in which plotting was executed. Contours were plotted in short segments as each grid row was swept, causing numerous pen lifts, restarts, and disk accesses. Much less wear on the plotter and pen points could be achieved if an intermediate plot file was created to direct rapid plotting that would follow contours rather than grid rows to connect short contour segments.

Operation of the SMOOTH CONT program was very similar to ROUGH CONT. Plotting smooth contours for the Timbercreek II site took approximately 25 minutes compared to twelve minutes for rough contour plotting, but the smoothed contours more closely resembled the existing contour map (Appendix H, Graph H.3). ROUGH CONT should be used for rapid modeling and analysis, while SMOOTH CONT is best suited as a follow-up program to produce contour plots of higher quality.

EW PRNT and EW PLOT. Earthwork volumes were calculated between the existing grid (DTIMEM) and the proposed topography grid (DTIMP). Printing and plotting cell-by-cell earthwork quantities was time consuming because of how the proposed topographic grid was created. To use the 3-D PLAT program for superimposing the site design upon proposed topography, it was necessary to compile elevations of the entire site, not just regraded areas. The proposed topography base was built

by first copying the existing topography grid to ensure that elevations in non-graded areas would be identical between the grids. The D-MODEL program was then used to overwrite areas of existing elevations to reflect proposed elevations. Because all elevations had reliability indices of 100, there was no way to exclude existing and proposed grid points having identical elevations from processing by the earthwork printer and plotter programs. As a result, much of the output was consumed in reporting earthwork quantities of zero. Since the balance of cut and fill is the primary concern of designers, it was found to be more expedient to simply choose the program option that reported summary earthwork totals. It is recommended that calculation of cell-by-cell earthwork volumes be reserved for larger sites in which more detailed earthwork analysis is required for planning optimum excavation cycling.

For the Timbercreek II site, total cut was calculated as 1965.85 cy and total fill was calculated as 2332.70 cy (Table 3.4). No shrink or swell factors were applied so the quantities could be compared to the other earthwork programs employing the average end area methods. It should be noted that earthwork quantities calculated by the PacSoft programs do not represent subcut or subfill volumes, but the total cut and fill which includes (or excludes, depending on location) topsoil stripped, topsoil replaced, and pavement metal. A valid earthwork comparison necessitated replanimetering the drawn sections so the areas between existing and proposed grades reflected total cut and fill. The earthwork totals calculated through the PacSoft EW PRNT program were relatively close to totals calculated through the average end method using planimetered sections (Tables 3.4 and 3.5).

Table 3.4. Comparison of earthwork volumes calculated through the PacSoft EW PRNT program and replanimetered drawn sections (represent total cut and fill rather than subcut and subfill quantities) using the average end area method.

	Cut (cy)	Fill (cy)	% Difference
PacSoft EW PRNT (grid model)	1965.85	2332.70	3.84%
Replan. sections (avg. end)	1890.34	2498.84	-6.65%

These results show the TOPOGRAPHY earthwork programs to be powerful modeling options because earthwork feasibility can be quickly determined whenever proposed landform is entered or modified through the digitizer.

**3-D PLAT.** The 3-D PLAT program is a useful program for analyzing how well proposed site development conforms to existing or proposed topography (Appendix H, Graphs H.11 and H.12). Being able to three-

Table 3.5 - Comparison of earthwork volumes calculated by the less accurate, but faster, baseline average end area method (CIVILSOFT & MFE), truncated prism method based on grid cells (PacSoft), and manual earthwork estimates based on planimeted cross-sections.

Timbercreek II  
Manhattan, Kansas

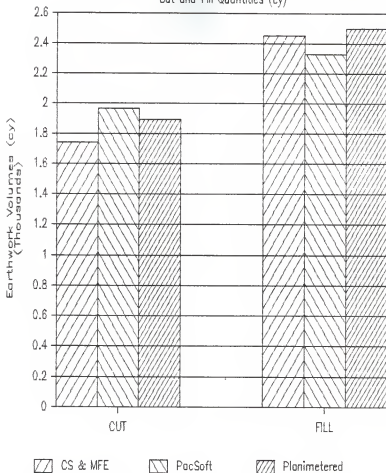
EARTHWORK COMPARISON TABLE - Cut and Fill Quantities  
(All earthwork volumes are in cubic yards)

Station	CS & MFE - Avg. End (Baseline Method)				PacSoft - Truncated Prism Method				Planimetered	
	Cut	%	Fill	%	Cut	%	Fill	%	Cut	Fill
0										
0 + 31	0.0	0.0%	7.2		Not Applicable		Not Applicable		3.1	0.0
0 + 39	0.0	0.0%	1.9		Calculated by grid cells		Calculated by grid cells		8.3	0.0
0 + 81	194.4	25.6%	0.0	0.0%					261.3	0.0
1 + 37	660.8	-26.1%	0.0	0.0%					523.9	12.0
1 + 88	141.8	49.1%	0.9	95.5%	V		V		278.5	20.2
2 + 22	50.2	43.4%	6.4	50.2%					88.6	12.9
2 + 82	88.2	26.4%	125.4	12.0%					119.8	142.6
2 + 99	58.2	9.4%	51.4	6.6%					64.2	55.0
3 + 53	238.7	3.3%	130.9	7.6%					246.8	141.7
4 + 09	121.6	12.9%	327.3	3.2%					139.5	338.2
4 + 26	28.3	-5.2%	159.6	-0.7%					26.9	158.5
5 + 16	127.3	-27.9%	1023.5	-0.8%					99.5	1015.7
5 + 37	15.5	-1.5%	262.8	-1.9%					15.3	257.8
5 + 85	16.9	-18.5%	335.9	-3.2%					14.3	325.5
6 + 05	0.7	-100.9%	20.3	-7.9%					0.3	18.8
6 + 20	0.0	0.0%	0.6						0.0	0.0
Total	1742.58	7.8%	2453.98	1.8%	1965.8	-4.0%	2332.7	6.6%	1890.3	2498.8

Note: % = Percentage difference compared to planimeted estimate

# EARTHWORK COMPARISON GRAPH

Cut and Fill Quantities (cy)



Graph 3.6 - Bar graph of cut and fill earthwork quantities based on Table 3.5.



dimensionally view the footprint of proposed site development upon a particular site could be used as an effective presentation tool for selling a design to a client who may not be able to visualize a design shown in plan view. Procedurally, the program is rather involved because a separate coordinate file describing the site layout, as well as a plot sequence file used to connect the points, must be created. Numerous mistakes were made when entering the northings and eastings for locating layout points. The best way to ensure the correctness of point coordinates is to first plot the site layout in plan view (Appendix H, Graph H.11) by specifying a rotation of 0 and a tilt angle of 90. After the plan view is satisfactory, the rotation and tilt values can then be set to correspond with the specifications used to plot the three-dimensional landform grid. Clarity was enhanced by plotting the site layout in a different color from the landform plot.

Creation of the plot sequence file is made much easier if points of the coordinate file are entered in the same order that plotting will follow. In this way, a "thru" command may be used in which only the beginning and ending points need to be specified. Despite a short and efficient plot sequence file, plotting was rather slow with frequent up and down pen movements.

Establishing the site layout coordinates, entering the values, and editing mistakes proved to be a time consuming and tedious process. Some of this tedium might be eliminated by using other dedicated drafting programs like the HP 38042 Surveying program or CEADS, and then using a PacSoft utility program to translate the coordinate data into a format acceptable by 3-D PLAT. The 3-D PLAT program itself could be significantly enhanced by including an option to accept layout coordinates from a digitizer.

Remaining Modules. The remaining modules of VECTOR, SLOPE, XSECT, PROFILE, and I-MODEL were previously described in a general sense and will not be reviewed in greater detail, but output examples are presented in Appendix H.

#### TOPOGRAPHY (PacSoft) - Error Handling

Error handling procedures were tested by typing nonvalid responses for entry prompts. Since pressing the <End Line> key is required for entering responses, nonvalid choices were not locked out. All errors from nonvalid responses were recoverable, however, by a repeat of the prompt or a return back to the main menu. Whenever more serious errors occurred, it was usually possible to restart the programs by pressing the <Cont> or <Run> keys. In some instances, however, the programs became unresponsive (requiring temporarily shutting the machine off) if commands were sent to peripheral devices that were not properly readied.

File utility procedures greatly reduce the chance of losing large blocks of data because programs automatically save data at frequent intervals. Generally, file closing procedures require users to exit programs through the specified "exit" menu option.

A condition was encountered in the EDIT program that was first thought to be an program error. When editing elevations in a TOPO file, an erroneously large elevation was entered that was not immediately discovered. Later, when the EDIT program was re-entered to correct the elevation for the second time, the summary maximum and minimum elevation headers at the beginning of the file were not automatically updated. Consequently, the 3-D plots were compressed and could not be re-scaled. After telephoning PacSoft technical support staff, it was learned that the EDIT program is set up this way so users can force different TOPO files to be plotted at the same scale, even though the maximum or minimum elevations "internally" contained in the files are different. The elevation range headers were easily updated by simply opening and then closing the file using a different data input program such as D-MODEL or I-MODEL. It would be good if the documentation described this condition.

### TOPOGRAPHY (PacSoft) - Documentation

Program documentation for the TOPOGRAPHY system is a definite software strength. Overall organization is provided through a "Table of Contents" and through page numbering prefaced by section numbers. No index is provided, but documentation brevity and format layout facilitates rapid perusal to find needed information. Each section begins with a one to four page introduction which succinctly describes program features, overall operation, and underlying algorithms. Most sectional descriptions contain ample illustrations to reinforce the text. The remaining portion of each section is devoted to a numbered, step-by-step operating procedure. Two-column format is used where the left column lists the screen display and the right column lists instructions of how the user should respond to prompts.

The writing style is clear and no difficulties were encountered concerning how to operate the programs. Clarity is further enhanced by appendices including a glossary, file structures, and program limitations and helpful hints. No written or disk-based tutorial is provided.

Technical support available through written correspondence and telephone assistance was superlative. Hardware access problems and the need to switch computer models forced a format change from 3 1/2" to 5 1/4" program disks. PacSoft was extremely cooperative and exchanged the disks within a week of time. PacSoft also provides technical support through a toll free telephone number that is easy to remember (1-800- PACSOFT). All telephoned questions were competently answered with no delays. Because engineering-type software is not generally available through local vendors who have in-depth knowledge of its operation, PacSoft's first-class telephone support should be considered a valuable characteristic of its utility.

### TOPOGRAPHY (PacSoft) - Application to Landscape Architecture

Overall, use of the PacSoft TOPOGRAPHY DTM software by landscape architects will likely be limited. For small- to medium-sized site

development projects involving lower landscape architectural fees, the cost of acquiring the TOPOGRAPHY software and necessary hardware would be difficult to recover in exchange for nominal time saved in design development and production. One notable exception would be the D-MODEL, 3D-GRID, and EW PRNT programs which do allow alternate grading plans and associated earthwork to be compared with acceptable accuracy (>90%) in a few hours time. Use of the TOPOGRAPHY system would likely be more cost effective for larger scaled sites considered for subdivision or reservoir/park construction.

The TOPOGRAPHY system performs many different graphic and computational functions that are not available on many single-purpose programs. Yet, when focusing on a specific application, the TOPOGRAPHY system can be expected to be outperformed by narrow-ranging, dedicated programs.

There are two complementary parts of landscape design, and the TOPOGRAPHY system is not exceptionally useful in either. In the first half of landscape design, the landscape architect requires a highly interactive medium through which design ideas can be conceived, expressed, and evaluated. Because TOPOGRAPHY graphics are not screen-based, it would be difficult to design through the computer --landscape architects would prefer the ease, fluidity, and immediate feedback obtained by simply sketching on paper. Once a design is worked out on paper and transferred to the computer, the TOPOGRAPHY system is best used as a tool to provide three-dimensional views and test feasibility by calculating earthwork. The most noted shortcoming of the system, though, is its overall cumbersomeness of use. For example, until a landscape architect can take a light pen or cursor positioning mouse and point on the screen to take a topographic section which extends from "here" to "there" (as opposed to creating coordinate and baseline files), the system cannot be considered highly interactive. The software would also be more useful if the topographic model base could be graphically linked to other programs facilitating the design and calculation of subsurface utility systems.

Even as a tool in visual impact studies, dedicated landform depiction programs like PERSPECTIVE PLOT (described in Chapter 4) that are in the public domain would be preferable over the TOPOGRAPHY programs. TOPOGRAPHY programs provide orthographic projections rather than true perspectives, and do not allow the superimposition of graphic shapes like buildings, trees, and powerline towers upon the landscape.

The second half of landscape design is expressed through two-dimensional drawings usually shown in plan which communicate existing contours, proposed grading, road and utility profiles, site layout and dimensioning, and landscape construction details. The TOPOGRAPHY system offers some assistance to designers in the first three applications, but is not as effective as dedicated CAD packages comparable to what architects use for laying out floor plans or engineers use for component design and drafting. Unlike the TOPOGRAPHY software, screen-based dedicated CAD drafting packages often include powerful functions

such as panning, zooming, and automatic scaling. Further, these CAD packages allow a layering of detail at the same scale or increasingly fine resolution.

Basing the TOPOGRAPHY package on a rectangular grid system did not seem to be a major hindrance. Even though some programs like contouring and earthwork were slightly less accurate than other software utilizing different calculation methods, the processing speed and integration of the TOPOGRAPHY programs enhance its use for topographic modeling. As an analytic tool that is less expensive than some dedicated microcomputer or minicomputer CAD systems costing tens or hundreds of thousands of dollars, the TOPOGRAPHY system should at least be considered for purchase by landscape architects who intend to use it for specific applications.

## EVALUATION CONCLUSIONS

After operating and becoming familiar with the programs submitted by CIVILSOFT, MFE Associates, and PacSoft software companies, the following conclusions were drawn:

1) The programs are faster than manual techniques and will produce results accurate within 90% or better compared to manual estimates. For all the programs tested, preparing the data for input was the most time consuming task. Once the data were entered, verified, and corrected as necessary, execution of the programs took a very short time. Calculation of the earthwork estimates was nearly instantaneous, while interpolation of contours (CIVILSOFT) took up to 80 minutes -- still less time than manual plotting.

The contour program by CIVILSOFT was impressive because of its reliance upon triangular irregular networks (TIN) enabling gridded elevation points to be intermixed with random spot elevations. This allowed areas of critical topography (swale flow lines, ridge break lines, low points, and high points) and areas of abrupt grade changes (curbs and structural walls) to be accurately defined. The pen plotting capabilities are highly developed and use of a plotter accommodating 24" x 36" paper (not available for the evaluation) is recommended for practical application; otherwise base map preparation will require enlarging the contour plot.

The PacSoft CONTOUR program is one of many available options which act upon a common data base. Elevations can be entered through the keyboard, a digitizer, or from a series of templates or cross-sections. Execution time is variable because the user can select rough or smoothed contouring. Accuracy is impaired somewhat because of the grid format in which random points are interpolated to the nearest grid intersection. Important topographic features may be lost unless the grid scale is appropriately scaled. PacSoft will soon offer a contouring option based on the TIN model.

The CIVILSOFT and MFE earthwork programs based on the average-end area method yielded identical results accurate to 99.9% of planimetered estimates (Graph 3.1). Earthwork calculation accuracy depends upon the number of cross-sectional points entered and the accuracy in estimating x,y coordinates. Suspicious discrepancies between computer and planimetered estimates prompted rechecking which revealed mistakes in both planimetered sections and estimated x,y coordinates. Quick estimates using only whole number contours measured directly off the contour plan, as recommended in the documentation, were accurate to within 92.2% for subcut quantities and 98.2% for subfill quantities compared to planimetered estimates. Accuracy is subject to variation depending on the topography. The number of points entered will also determine how much time the programs save over manual estimations, but rough computer estimates are definitely faster than a person proficient with a planimeter. Users of both programs are strongly advised to select program versions which allow digitized input--time savings

will be substantial. Overall, MFE's program is slightly more useful for site design and analyzing grading alternatives because cross-sections can be vertically exaggerated on the screen, grade intersection points are calculated and printed, and separate existing and proposed data files allow different file combinations for earthwork comparisons.

The PacSoft earthwork program, as part of a digital terrain modeling package, is intended to augment preliminary decision making rather than calculate highly accurate earthwork estimates. For end area earthwork estimates, the X-Link module of the software package can be used in conjunction with the HP38042 Volume H Earthwork program available through Hewlett Packard. Earthwork volumes for the TOPOGRAPHY earthwork program are calculated through the truncated prism (borrow pit) method. For the Timbercreek II site, the earthwork volumes calculated by the PacSoft EW PRNT program were within 96.2% (cut) and 93.4% (fill) of the average end estimates (Graph 3.6). The program is useful for modeling site grading because the proposed surface grid can be adjusted up and down to find the most economical earthwork balance. Shrinkage and swell factors can also be applied to the volume estimations.

2) Program acquisition costs must be carefully weighed against anticipated level of use and office size. Costs of the average end earthwork programs (CIVILSOFT: \$490, MFE: \$300) should be recouped in a reasonable amount of time by even small landscape architectural offices if earthwork calculations are performed on a regular basis. Besides the cost savings in personnel time required to produce earthwork estimates, staff time is saved because the earthwork documentation is immediately ready for project filing. Cost of CIVILSOFT's CONTOUR program must be analyzed more closely. In addition to the initial program cost of \$790, a large format plotter is required if the contour plots are to be used as base maps. Since ground or aerial based survey companies normally assume production of contour maps from field data, landscape architectural firms may not want to invest in a contour plotting program if it will be infrequently used. An exception would be if grading plans are prepared exclusively through spot elevations where contours must be interpolated.

PacSoft's TOPOGRAPHY software should be selected and purchased in program groupings targeted for a particular application. Purchasing a single program is expensive because it is necessary to purchase supplemental programs for building the data base. The power of the programs resides in their linked use. If a landscape architectural firm desires to perform site modeling based on a grid system, then a commitment must be made to invest in a "package". Several TOPOGRAPHY options are particularly recommended for use by landscape architects for site design (Table 3.6).

Table 3.5. Recommended TOPOGRAPHY package options.

Option	Series 200	9845	Series 80
Base System (coord. & grid input)	\$1000	\$1000	\$800
Contour Mapping	750	750	650
Profiles & Cross Sections	600	600	550
3-D Projections	450	450	400
Earthwork Volumes	750	750	650
Digitized Modeling	350	350	300
Interactive Modeling	500	500	450
3-D Plat	750	750	600
Total	\$5150	\$5150	\$4400

3) The software programs were generally hard to use. Entering data for the CIVILSOFT and MFE programs was tedious because all entries required use of the keyboard. Looped entry sequences force the user to enter data in blocks which must be finished before editing or temporarily quitting. Editing was generally troublesome unless performed through a word processing program. Users accustomed to full screen editing will disdain linear sequences of specifying list ranges and point numbers to be corrected. Performance atones for some of these difficulties of use.

PacSoft's TOPOGRAPHY software was generally easier to use since data input and interaction can be optionally directed through a digitizer. When building a gridded data base through the keyboard, an edit option automatically generates the row and column spatial coordinates and only requires the user to input elevations. The most significant shortcoming of the modeling package is that the landform image cannot be displayed and manipulated on the screen.

4) CIVILSOFT and MFE programs operate well as stand-alone programs, but are not part of an extensive, graphic based site design package. The contouring and earthwork programs perform well according to their intended function. As a design tool, however, the programs are not yet part of an extensive CAD package. The programs can be conveniently used during the preparation or conclusion of site design, but do not concurrently operate with other interactive programs during the evolution of design.

5) Modular design of the PacSoft TOPOGRAPHY software makes it a comprehensive digital terrain modeling package adapted to microcomputers, yet landscape architects are still in need of a screen-based, more highly interactive three-dimensional design package that runs in a multi-processing environment. A need remains for computer-assisted software specifically written for landscape architects which combines digital terrain modeling with sophisticated CAD-style features like zooming to capture intricate detail. Such an idealized system needs to be highly interactive through three-

dimensional screen graphics and operate in a multi-processing, multi-windowing environment in which concurrently running design modules share common information. Ease-of-use will need to be highly developed before landscape architects are ready to abandon pencil and paper when designing.



## INVENTORY OF PROGRAM FEATURES

Graphic Terrain Modeling & Earthwork Software  
 Compiled April 1985

PROGRAM NAME	CONTROLS	EARTHINK II	EARTHINK II	TOPOGRAPHY SYSTEM
CIVILSOFT				
Graphic Terrain Modeling & Earthwork Software Compiled April 1985	270 S. Anabasis Blvd., Suite 100 Anaheim, CA 92805 (714) 999-5001	NFE Associates, Inc. P.O. Box 851 Aberyst, MA 01004 (413) 253-7066	PackSoft, Incorporated 330 Fourth Street Kirkland, WA 98033 (206) 837-0051	
COST	\$770	\$490	\$200 (IBM), \$200 (Apple)	Cost depends on options
Hardware Required / Peripherals Supported				
Host computer	IBM-PC, Apple II and 40 others			
Display screen	monochrome (no graphics for EM) color			
Printer	Epson or equivalent			
Asynch. communications adapter	RS-232			
Graphics card required	color graphics monitor adapter			
Digitizer(s)	no			
Plotter(s)	HP III, Modelmaster Comp., Alpha-Metric			
Disk Format(s)	5 1/4", 8" (CP/M-80 only)			
Software Design				
Operating System	MS-DOS 2.0, CP/M-80			
Minimum system memory	512K (full graphics) 256K (16 bit each.)			
Language level	machine code			
Multi-window displays / processing	no			
Program driving system	menu			
Program status annunciators	yes			
Modification of program by user	no			
Use of function keys	no			
Help Screens	no			
Random return to main menu (ez)	no			
File Utility Operations				
File type	ASCII			
Disk storage of data	yes			
Disk storage of calculated results	yes			
Data linking/transfer	CIVILSOFT C680-PC			
Overwriting confirmation	yes			
File type	ASCII			
Disk storage of data	yes			
Disk storage of calculated results	yes			
Data linking/transfer	CIVILSOFT MCH			
Overwriting confirmation	yes			
File type	ASCII			
Disk storage of data	yes			
Disk storage of calculated results	yes			
Data linking/transfer	CIVILSOFT MCH			
Overwriting confirmation	yes			

PROGRAM NAME	CONTOUR (CS)	EARTHINK II (CS)	EARTHINK II (MFE)	TOPOGRAPHY SYSTEM (PS)
Data Input / Manipulation				
Keyboard entry	yes	yes	yes	yes
Digitizer supported	no	under develop.	under development	yes
Mouse supported	no	no	no	no
Data preparation needed	limited	yes	yes	generally no
Data entry by				
regular grid points	yes	NA	NA	yes
random points	yes	yes	yes	yes (converted to grid)
Up/down screen scrolling	down	down	down	up/down
Data editing through text editor	yes	yes	yes	dna
No. of input points	750	1500 (50x 30/run)	2000 (50x 40/run)	1000 / batch
Multiple runs / continuation or splicing	yes/no	yes/yes	yes/no	yes/yes
Graphics				
Scaling - Screen/Printer	auto. scaling	auto. scaling	variable	not supported
- Pen Plotter	variable	variable	not supported	variable
Data / plot labelling	yes	yes	yes	yes
Plotting device	scn./print, p.-plotter	scn./print, p.-plotter	scn.-printer (thru BBS)	pen plotter
Plan contour plotting				
Contouring method	TLN	NA	yes (rough)	grid interpolation
variable contour intervals	yes	NA	pt.-to-pt.	yes
labelled contours	yes	NA	no	yes (outside graph)
grid starts/point markers	yes	NA	no/yes	yes
descriptive labels	(10 char.)	NA	no	no
indication of heavy contours	yes	NA	no	yes (two-step plot)
cross-sectional displays	no	NA	no	yes
variable contour rounding	yes	NA	no	yes
Cross-Section Plots				
stationing	NA	yes	yes	yes
pt.-to-pt. connection / splice smoothing	NA	pt.-to-pt.	pt.-to-pt.	pt.-to-pt.
graphic painting of cut/fill areas	NA	no	no	no
existing - future profile labelling	NA	yes	no	yes
selectable vertical exaggeration	NA	yes (pen plots only)	yes (screen, printer)	yes (pen plots)

Continued

PROGRAM NAME	CONTOUR (CS)	EMTHK II (CS)	EMTHK II (NFE)	TOPOGRAPHY SYSTEM (PS)
Graphics - Continued				
Three-dimensional plotting				
orthographic/perspective	NA	NA	NA	orthographic
rapid, rough plotting	NA	NA		yes
plot smoothing	NA	NA	NA	yes
cross-sectional displays	NA	NA	NA	yes
random cross-sectioning	NA	NA		yes (thru coord. file)
polygon shading	NA	NA	NA	no
transformations (x, y, & z axes)	NA	NA	NA	yes
vertical exaggeration	NA	NA	NA	yes
hidden line removal	NA	NA	NA	no
view from "within" BTH	NA	NA	NA	no
Earthwork Calculations				
Earthwork method	NA	Average end / prism.	Average end	truncated prism
Calculation units	NA	Engl. (cu) / Metr. (cu)	Engl. (cu) / Metr. (cu)	cu or cu
Incremental cut/fill volumes	NA	yes	yes	yes, per cell
No-cut/no-fill pts. printed & plotted	NA	no	yes	NA-WF lines plotted
Alternative proposed grades	NA	no	yes	yes
Insert, delete, append points w/ station	NA	yes	yes	yes
Insert, delete, append stations	NA	no	yes	NA in earthwork
Change station value	NA	yes	yes	NA in earthwork
Allowance for shrink(1), swell(2)	NA	yes	no, no	yes, yes
Summary mass ordinate table	NA	yes	yes	total or summary per cell
Documentation (User's Manual)				
Layout and Format				
Typeset or typewritten	typewritten	typewritten	typewritten	typeset
tabbed sections	no	no	limited	no
bold print subheads	no	no	no	yes
two-column (display/instruction) format	no	no	no	yes
two color printing	no	no	no	no
single screen images/angle diagrams	yes	yes	no	no / yes
binding	8 1/2" x 11" 3-ring	8 1/2" x 11" 3-ring	8 1/2" x 11" 3-ring	8 1/2" x 11" 3-ring

Continued

PROGRAM NAME	CONTOUR (CS)	EARTHINK II (CS)	EARTHINK II (PFE)	TOPOGRAPHY SYSTEM (PS)
Documentation - Continued				
Content				
set-up instructions	yes	yes	yes	yes
table of contents	yes	yes	yes	yes
comprehensive index	no	no	no	no
glossary	no	no	no	yes
crossed summary card	NA	no	NA	NA
trouble-shooting guide	error messages	error messages	limited	limited
Technical program and file info.	file config.	file config.	no	yes
Written/format clarity	good/good	good/good	good/fair	good/excellent
tutorial section				
written tutorial w/ examples	yes	yes	yes	no
interactive on-disk tutorial	no	no	no	no
sample files on disk	yes	yes	yes	no
Purchaser support				
toll-free telephone assistance	no	no	no	yes
technical support	delayed, good	delayed, good	may be delayed, good	rapid, excellent
software upgrade plan	yes, \$500 cost	yes, \$500 cost	yes	yes
software replacement plan	yes	yes	yes	yes
disk media warranty	no	no	1 year	yes
availability of custom programming	yes, \$25	yes, \$25	yes	yes
separate purchase of documentation	yes, \$25	yes, \$25	yes	yes
demo disk available	no	yes, \$10	yes	yes
leasing or renting option	no	no	no	renting

NA = Not Applicable

dna = data not available or unknown

## CHAPTER 4 IDEALIZED COMPUTER-ASSISTED SITE DESIGN SOFTWARE

Throughout the software evaluation, numerous references were made to the need for an integrated computer assisted site design (CASD) package expressly written for landscape architects. The digital terrain modeling software offered by PacSoft, and executable on a microcomputer, most closely approaches the idealized model, yet inherent shortcomings preclude its widespread use among landscape architects. Even if landscape architects are not the technical developers of an idealized CASD package, they can promulgate development by outlining functional specifications from the viewpoint of eventual users. How might an idealized CASD package appear and how would it work? This chapter discusses that question in greater detail by describing the three digital terrain models available for landform depiction, the need for integrating design activity modules, and software development standards.

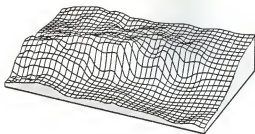
### IDEALIZED COMPUTER-ASSISTED SITE DESIGN SOFTWARE - DESCRIPTION

#### A GRAPHIC-BASED SYSTEM

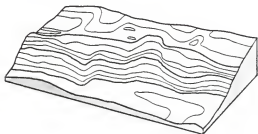
Foremost, the CASD package will need to be structured around three-dimensional computer graphics. Inundating information to be considered during design can most easily be communicated through graphics. Graphics also emphasize form and the relationship between variables. The single element common to all site design is topography. A CASD package should therefore be rooted in the graphic depiction of landform.

Currently there are three models available for depicting landform: the rectangular grid model, the contour line model, and the triangulated irregular network model (Fig. 4.1). Variations of these wireframe models can employ other representational techniques such as hill shading, slope gradient and aspect mapping, section cutting, and surface cover thematic mapping. Literature searches show that most of the research directed at topography modeling has been produced by geographers and cartographers.

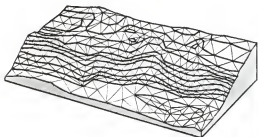
The topographic model of most common familiarity is the three-dimensional oblique block model based on a rectangular grid. Like PacSoft's TOPOGRAPHY package that was evaluated, this form of surface representation has been the basis of a number of three-dimensional plotting packages like SURFACE II (Sampson, 1975) or more novelty type microcomputer programs that have been produced in recent years. One useful rectangular grid modeling program that continues to be used by foresters and landscape architects for visual impact assessments of forest clear cuts, ski runs, and powerline routing (Figure 4.2) is the PERSPECTIVE PLOT program developed by Devon Nickerson (1980) for the U.S. Forest Service. More widespread use of PERSPECTIVE PLOT is restricted, however, because the program is only available for Hewlett Packard computers and specialized peripherals.



a). Rectangular grid model  
(Sampson, 1970).



b). Contour line model  
(no database linkage  
between contour lines).

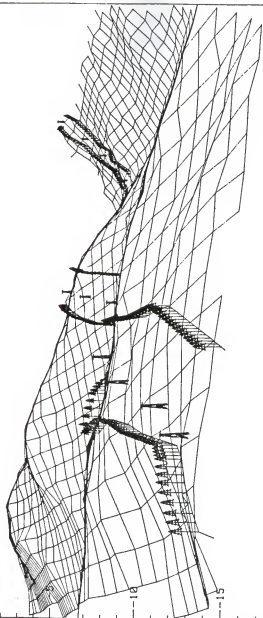


c). Triangulated Irregular  
Network (TIN) model.

Figure 4.1 - The three forms of three-dimensional digital terrain models.

ConSoGen Powerline

VIEW DIST: 23 INCHES  
VP: Hwy 98 REST STOP



PERSPECTIVE PLOT

102

112

122

35mm CAMERA WITH 53mm LENS

Figure 4.2 - Powerline routing simulation using the PERSPECTIVE PLOT program developed for the U.S. Forest Service (Nickerson, 1980, p.16).

In all of these programs the third dimension of topographic elevation is stored in a two dimensional array. Data storage requirements are modest because the row and column structure of the array implicitly describe the spatial relationship (x,y coordinates) of elevation points. Graphic displays are easy to produce since the array structure is amenable to looped program routines. Oblique displays allow the user to view the surface in three-dimensions from any inclination angle or rotation.

As demonstrated through the software evaluation, grid digital terrain models have several disadvantages for site design. The most basic problem is that important topographic features such as high points, low points, ridge break lines, and swale flow lines rarely coincide with grid intersection points. If the grid cell size is scaled smaller to capture these features, grid points falling across uniform surface areas become redundant. Second, cross-sections taken at skewed angles to the perpendicular grid lines have fewer points available for interpolation and are less accurate than sections taken along the axes. Third, vertical grade changes like those characterized by a curb, retaining wall, or superimposed building cannot be accurately represented since points along a grid axis can only have a single elevation value (Figure 4.3)

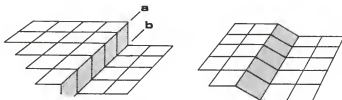


Figure 4.3 - In plan view, the grid lines A and B needed to depict a vertical grade change would be superimposed, resulting in each point on the line having two different elevations -- an impossibility with grid-based models. Vertical grade changes are distorted when offset a full grid cell width (right figure).

Finally, many modeling procedures of a CAD package such as drainage analysis are more concerned with the orientation of connecting lines than discrete elevations (Heil, 1979). Drainage flow lines do not follow right angle changes in directions represented by rectangular facets.

The second type of topographic model is composed of three-dimensional contour lines. Landscape architects are experienced with contour maps so this type of model closely parallels how they visualize and manipulate landform. Unfortunately, while the displays are visually effective, each contour line is individually interpolated and plotted. There is no data structural link between adjacent contour lines. Modeling procedures such



as grading which depend upon searches of neighboring points are slow because every single point of adjacent contours must be analyzed (Peucker, 1977).

The third topographic model type currently receiving the most attention is based on triangulated irregular networks (TIN). For site design modeling, TINs offer the advantages that topographic points can be random and triangulated connections provide a continuous surface network. According to Mirante and Weingarten:

Such networks can be used to describe almost any surface, including those with holes, irregular boundaries, or vertical surfaces. Contour cutting and mathematical operations such as cut-and-fill calculations are easily performed on the TIN. Compared to rectangular grid techniques, the TIN produces more accurate surface representations with less data storage.

(Mirante and Weingarten, 1982, p.11)

Spot elevations correspond to triangle nodes and contours or structural lines correspond to triangle edges. Applications involving TINs incorporate one or more processes (Peucker, Fowler, and Little, 1979):

- 1) Sequential node-by node processes;
- 2) Searches for adjacent nodes or locating a point within a triangle; or
- 3) Tracing junction lines between intersecting surfaces.

Triangulated irregular networks are particularly attractive for interactive modeling because point insertions or deletions upon the topographic surface can be easily accommodated. In the case of inserting a point within a triangle, the facet is subdivided into three smaller triangles (Fig. 4.4). The acceptance of random points allows points to be concentrated where most needed to describe areas of unusual topography.



Figure 4.4 - Subdividing a triangular facet into three smaller facets through point insertion using the TIN model.

Data structures of TINs and computer algorithms which trace the connectivity of nodes are ideally suited for programs that assist in site grading, drainage design, road alignment, and the layout of site elements. Robert Snyder (1984) of the University of Illinois has already done much work in describing the functions and proposed data structures for development of these TIN-based programs.

## INTEGRATION OF MODULES

Decisions made during site design depend upon simultaneous considerations of aesthetics, economics, and construction feasibility. Site design software needs be equally broad in its conception and structuring. Modular design is a common software development technique which reduces a complex software system into smaller components of manageable size. Modules conserve dynamic computer memory, provide flexibility by operating in different combinations, and reduce data duplication through linkages in which data is shared.

The host environment of an ideal CASD software package would establish the overall screen format and control system utility functions like data base input and management, file operations, and linking modules. Modules would represent individual design activities like "site grading", "road alignment", "storm drainage", or "site element layout". As envisioned, the computer screen would be set up as a blank graphic window surrounded on two sides by a text pad which displays module names, file names, menus, module functions, and input messages (Fig 4.5).

Design would begin by building a graphic model of existing landform by transferring topographic data from digital tapes, photographic data capture techniques, or tracing contours on a digitizer. The designer would summon the graphics module and generate a three-dimensional computer image according to specified parameters. Next, a site analysis module could be summoned. Depending on the amount and type of information residing in the data base, module options might include slope shading, drainage network tracing, vegetative or soil mapping, solar gain determined by slope aspect, or seen areas from any point.

The designer would continue by summoning the site layout module. Site elements could be freely drawn on the landform model with a light pen or described by digitized inputs. Grading would be accomplished through the grading module which opens by having the user set values for warning indicators that would be activated, for example, if slopes were graded too steeply. Grading through spot elevations would be performed through cursor positioning and numeric keyboard entries. Freeform grading would involve moving a graphic icon "blade" to sculpt the landform image as cut and fill volumes displayed on the text pad are automatically calculated and totals are updated. Grading procedures would not necessarily employ contour manipulations unless the digitizer was used. At any time, the designer would be able to take and analyze a skewed cross-section viewed on a overlaid graphic window. Other windows might show gradients of subsurface storm drain pipes whereby inlet and daylight elevations could be studied in relation to surface grades. In a multi-processor environment, perhaps earthwork quantities or other takeoff figures could be concurrently exported to a financial spreadsheet for cost estimating. Module-by-module, the designer would be freely drawing, relegating computations to the computer, and considering different design alternatives -- all without touching a piece of paper. The power of the package is derived from the modules which work together, pass information, and follow the designer's inclination to work on several different design activities at once.

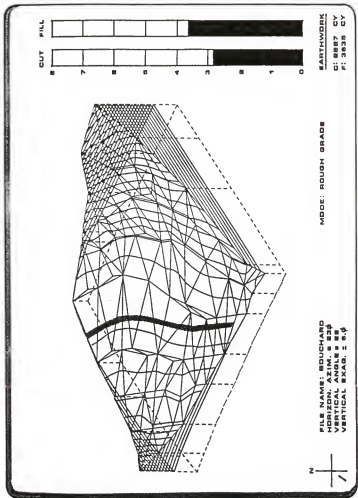


Figure 4.5 - Screen mock-up of idealized computer-assisted site design software. The road alignment and earthwork modules have been linked and are shown in use.

## SOFTWARE DEVELOPMENT STANDARDS

### EASE-OF-USE

Unless a CASD package is as easy to use as pencil and paper, or offers superlative computational or graphic advantages which outweigh operational inconveniences, it will fall into disuse. Ubiquitous keyboards are familiar input devices and suffice for answering input prompts and invoking functions through mnemonic commands. They should be avoided, however, for numeric data input, pointing, and cursor positioning. Designers will prefer to make fluid graphic manipulations through a digitizer, mechanical or optical mouse, light pen, joystick, or other similar device. Device status can be monitored by the software through frequent polling or program interrupts.

### HUMAN-COMPUTER INTERFACE

If the computer is to be effectively used as a tool for site design, the importance of the human-computer interface must be stressed. Norman (1984) cites four distinct stages of the human-computer dialogue: intention, selection, execution, and evaluation. Each stage of the dialogue has different goals, methods, and needs. Of the four stages, "Selection", may be considered the most important because it is the mode through which human intentions are translated into computer execution, which in turn, provides valid results for human evaluation. Designers must be able to easily convey their intentions through CASD module functions that can be rapidly selected with minimal error.

Module functions can be selected through menu listings highlighted by a cursor positioning mouse, or less preferably through the keyboard. However, if most of the human-computer interaction is being directed through the keyboard, experienced operators may resist moving their hands to a separate choice device. According to Shneiderman (1984), experienced operators often prefer to type up to six to eight characters rather than continually switch back and forth between input devices. Unless "pull-down" menus are used, menu displays should be nondestructive; that is, they should not clear the screen or otherwise disrupt graphics or text being worked upon. In multi-row menus, the lower rows may be reserved for submenu options or short descriptions which clarify highlighted main menu options. Finally, users should be allowed to freely ascend or descend menu levels while "exploring" without being irreversibly committed to a function sequence.

Another commonly used human-computer interface in CAD packages is providing control through a command language. Mnemonic commands composed of single letters or short three- or four-letter words allow rapid activation of software functions by experienced users who would otherwise feel restrained by having to step through a familiar menu. Development of a command language for an idealized CASD package should incorporate three vital tenets: command names given to functions should be predictable and consistent; the user should always be allowed to back-up or undo any activated function; and "garden-pathing" --allowing the user to progress too

far along an input sequence before error checks are invoked-- should be avoided (Branscomb and Thomas, 1984).

A CASD package as complex as previously described will require numerous screen indicators to inform the user what modules have been linked, what files are being acted upon, and what functions are being processed. Program feedback such as auditory cues, text messages, and graphic symbols will all assist the user in following program operation.

Finally, consistency should be maintained between modules. Similar functions common to all modules should be assigned to the same function keys. Assignment of function keys might also parallel conventions popularized by other popular software packages; for example, F1= Help and F2= Edit.

### ACCURACY

Interactiveness of site modeling performed on a computer dictates that graphical and computational accuracy be placed in context of the time required to produce the results. During the early states of computer-assisted design, it is advantageous to rapidly produce several design alternatives of moderate graphic quality and computational accuracy comparable to what is manually produced on tracing paper when doing design studies. The user should be able to switch into a rough design mode in which three-dimensional landform images are roughly plotted with no hidden line removal or slope shading. Likewise, computationally-based modules should use fewer data points. Later, when the final design is undergoing refinement, more sophisticated, accurate, and time consuming graphical and computational routines can be selectively reactivated. Additionally, multiple levels of design detail should be accessible through a "zoom" feature.

### MODIFICATION

It has been estimated that up to 75% of programming work involves program modification (Laughery and Laughery, 1985). Much costly post-release software modification can be avoided if programmers have a clear understanding of the CASD package goals, processes, and human-computer interface considerations before coding begins. Once a common database structure such as the TIN model has been precisely defined, related, but separate CASD modules will make the task of system upgrading more cost and time efficient. Modularization should also be applied when coding the user interface to circumvent major code revisions when the system is enhanced. Additionally, hardware peripheral addresses and operational codes should be assigned to easily changed global variables. Planned change is less costly change. Modification is most highly developed when the system is "open-ended" so the user can invent commands to perform the actions of several dedicated system commands, or create a customized menu.

### COMPATIBILITY

As the field of software engineering advances, software compatibility with recognized standards for file structures (ANSII), graphics (HALO and Core Graphics System sponsored by the Association of Computing Machinery),

program languages, and operating systems (PC-DOS, UNIX, and others) is a forefront consideration for greater software integration and interchangeability. An idealized CASD package should not only be internally integrated, but a substantial effort should be made towards ensuring compatibility with popular and relatively market stable word processing programs (for data editing), database management programs, spreadsheets, and other CAD systems. This principle of utilizing the power of other dedicated programs was demonstrated in the evaluation of the CIVILSOFT programs in which data were manipulated through WordStar and Lotus 1-2-3. Compatibility considerations should also be extended to include greater hardware ambivalence.

### CASD SOFTWARE DEVELOPMENT STRATEGIES

Currently there are several factors working against development of an integrated site design software package. Foremost is the general lack of financial resources to sponsor development. The requisite three-dimensional graphic routines and data base structure can be anticipated to be complex; certainly beyond the programming ability of most, if not all landscape architects.

Developing integrated site design software may be accomplished through one or more sources: commercial software companies, universities, public governmental agencies, large multidisciplinary design/engineering firms, and capable individuals in related professions.

Software Companies: Landscape architecture represents a relatively small commercial market and attracting outside developers and investors will be difficult. Landscape architects must therefore align themselves with civil engineers, cartographers, and land development groups who share common interests and needs. Cooperation and unified market clout will help entice interest of commercial software companies.

Universities and Publicly-funded Research Groups: Even though research conducted by universities and publicly-funded research groups is not directly motivated by profit potentials, these groups continue to expand the theoretical base upon which computer graphics, data base structures, and hardware innovations are sparked. Establishing cooperative ties, like those between the University of Kansas and the Kansas Geologic Survey in the development of SURFACE II, will become increasingly important if research subsidies continue to be cut.

Public Governmental Agencies: If individuals are willing to work in the bureaucratic environment of governmental agencies, then unique software development opportunities may be available because of the government's accessibility to technical resources. Groups such as the U.S. Forest Service permanently or temporarily employ individuals having widely varied technical backgrounds and special expertise. PERSPECTIVE PLOT was developed through a cooperative effort between

the U.S. Forest Service and logging specialist, Devon Nickerson. Governmental agencies are particularly supportive of software research and development when applications benefit natural resource planning and management.

Large Multidisciplinary Design/Engineering Firms: Multidisciplinary firms having adequate technical and financial resources continue to be innovative leaders in the development of computer-aided design systems. In-house computer specialists are able to approach software development from a designer's point-of-view, or have immediate feedback from designers who will eventually use the CAD system. Landscape architects who are employed in large multidisciplinary firms can exert more influence concerning the economic importance of sensitive site design. Bridling software development interest and directing it towards site design could help provide a competitive edge that many firms seek in times of escalating site development costs -- particularly in localities where land speculation is high.

Civil Engineering, Cartography, and Related Professions: Civil engineers and cartographers are actively pursuing research and development leading towards CASD software that meets their academic and practice needs. Landscape architects should closely monitor their progress and offer assistance when possible and appropriate. Computer-aided site design software developed in other professions should be critiqued for its application to landscape architecture. In many cases, it may be possible to adapt their CASD systems to better meet the practice needs of landscape architects.

Capable Individuals Within and Outside Landscape Architecture: As evidenced many times in creative and technical fields, truly innovative concepts, discoveries, inventions, and developments can surface from capable individuals working in seeming isolation. It is doubtful whether a comprehensive and complex CASD system for landscape architects could be developed by a single person, but individuals might conceive an algorithm or interactive device that could provide a breakthrough in subsequent CASD development. Funding groups within the landscape architecture profession should carefully scrutinize research proposals which reflect new ideas and approaches which could spark innovation, while offering promise for a reasonable return on the investment.

The American Society of Landscape Architects (through the Institute for Professional Practice or the Committee on Computer Applications in Landscape Architecture) could currently perform the needed service of sponsoring regular reviews of software emerging from related fields that approaches site design from piecemeal directions. In this way, functional specifications that have already been prepared for computer-assisted site design software for landscape architects can be modified to follow hardware and software developments. The successful emergence of CASD software for landscape architects will depend on being able to recognize when conditions and opportunities for development are ripe.

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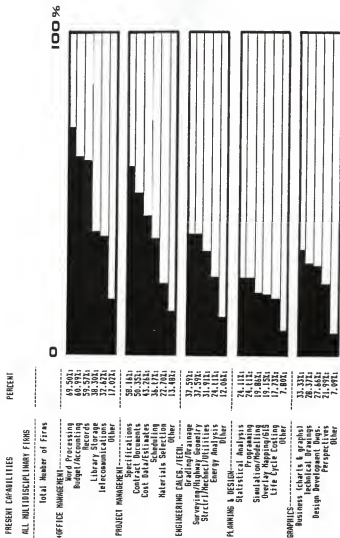
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**Table A.1 - Comparison matrix of 60 software companies and products.**  
(Schwendau, 1984).

COMPANY NAMES	1. CAD PRODUCT	2. PRICE RANGE (minimum)	3. TYPES OF PROJECTIONS	4. KINDS OF APPLICATIONS	5. PRODUCT CLASSIFICATIONS	6. INSTALLATION & TRAINING	7. HOURS TO LEARN	8. COMPUTER CLASSIFICATION
	CAD Software CAD Hardware CAD Systems	0-10,000 10,000-15,000 15,000-20,000 20,000-50,000 over 100,000	2-Dimensional 3-Dimensional	Mechanical Architectural Electronics Mapping Piping Others	CAD CAAD CAD/CAM CAE Others	Both Provided Installation Provided Training Provided	10 20 30 40 50	More than 5D Microcomputer Minicomputer Main Frame and Terminals
Adage								
Advanced Electronics Design								
Apollo Computer								
Autodesk								
Auto-tral Technology								
Aydin Controls								
Bausch & Lomb								
Bruning CAD								
CADAM								
CAD/CAL								
CAD/LINC								
CALDS								
Cardinal Engineering								
Celestial Software								
Computervision								
Daisy Systems								
Data Technology								
Design Futures								
Digital Equipment								
Enertronics Research								
Engineering Systems								
Evans & Sutherland Computer								
FutureNet								
General Robotics								
Gerber Scientific Instruments								
Harris Computer								
Hewlett Packard								
Honeywell								
IBM								
Information Displays								
Interactive Computer Systems								
Intergraph								
Lexidata								
McDonnell Douglas Automation								
Mentor Graphics								
Metasoft								
Microcomputer Graphics								
Micrograbs								
Micro Control Systems								
Personal CAD Systems								
PERQ Systems								
Prime Computer								
PSI Systems								
PWAL-REDAC								
Responsive Logic								
Scientific Calculations								
Sigma Design								
Spectrographics								
Summagraphics								
Summit CAD								
Telesis								
3Design								
T & W Systems								
Tricad								
Valid Logic Systems								
Vector Automation								
Vector General								
Versatec								
VIA Systems								
VLSI Technology								



Graph B.1 - Computer use by multidisciplinary and landscape architectural firms of all sizes having membership in the American Society of Landscape Architects (Clement, 1985).

## PRESENT CAPABILITIES

## ALL L. A. FIRMS

PERCENT

## Total Number of Firms

## OFFICE MANAGEMENT

Word Processing  
Budget/Accounting  
Records  
Library Storage  
Other

## PROJECT MANAGEMENT

Telecommunications  
Specifications  
Cost Data/Estimates  
Contract Documents  
Scheduling  
Materials Selection  
Other

## ENGINEERING CALC./TECH.

Grading/Drainage  
Surveying/Highway Geometry  
Struct./Mech./Utilities  
Energy Analysis  
Other

## PLANNING &amp; DESIGN

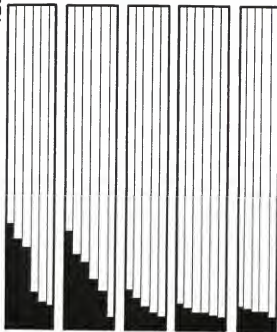
Programming  
Statistical Analysis  
Life Cycle Costing  
Simulation/Modeling  
Overlay Mapping/GIS  
Other

## GRAPHICS

Perspectives  
Business Charts & graphs  
Design Development Dwg.  
Technical Drawings  
Other

100 %

0



## APPENDIX C - ONLINE COMPUTERIZED SEARCH DATABASES

The following general interest online databases provide information relevant to computer hardware, articles appearing in computer-related periodicals, software availability and reviews, upcoming computer exhibitions, special interest user groups, and numerous other categories. The entries were excerpted from Glossbrenner's How to Buy Software (1984).

### CompuServe

5000 Arlington Centre Blvd.  
P.O. Box 20212  
Columbus, OH 43220  
(800) 848-8990  
(614) 457-8600

Initial subscription: \$20-\$50

Availability: Computer stores and bookstores

Hours of operation: 21 hours per day, user's local time

Costs: Prime Service (8:00 AM -6:00 PM): \$12.50/hour for 300-baud service; \$15.00/hour for 1200-baud service.

Standard Service (6:00 PM -5:00 AM): \$6.00/hour for 300-baud service; \$12.50/hour for 1200-baud service. Telenet and Tymnet charges are \$2.00 per hour extra. Users can use the CompuServe network in selected locales.

Monthly minimum fee: none

### The Source

1616 Anderson Road  
McLean, VA 22102  
(800) 336-3366  
(703) 734-7540

Initial subscription: \$100

Availability: Computer stores and bookstores

Hours of operation: 24 hours per day.

Costs: Prime Time (7:00 AM -6:00 PM): \$20.75/hour for 300-baud service; \$25.75/hour for 1200-baud service.

Non-Prime Time (6:00 PM - 7:00 AM): \$7.75/hour for 300-baud service; \$10.75/hour for 1200-baud service. Telenet, Tymnet, or Uninet charges are included in the above rates.

Monthly minimum fee: \$10 (\$9 is a credit against usage).



The Knowledge Index  
DIALOG Information Services, Inc.  
3460 Hillview Avenue  
Palo Alto, CA 94304  
(415) 858-3777

Ask for extension 415 when dialing the following numbers:

(800) 528-6050  
(800) 528-0470, in Alaska and Hawaii  
(800) 352-0458, in Arizona

Initial subscription: \$35  
Availability: Direct from DIALOG and computer stores and bookstores  
Hours of operation: 6:00 PM -5:00 AM, user's local time  
Costs: \$24/hour regardless of the baud rate. Telenet, Tymnet, and Uninet charges are included in this cost rate.  
Monthly minimum fee: none

Comments: The initial subscription includes a three-ring notebook of documentation and two hours of connect time. The Knowledge Index is a subset of DIALOG, one of the largest collections of publicly available online information services with over 150 individual database categories.

NewsNet  
945 Haverford Road  
Bryn Mawr, PA 19010  
(800) 527-8030  
(215) 345-1301 in Pennsylvania

Initial subscription: No charge  
Availability: Direct from NewsNet.  
Hours of operation: 24 hours/day  
Costs: Prime Time (8:00 AM -8:00 PM): \$24/hour for 300-baud service; \$48/hour for 1200-baud service.  
Non-Prime Time (8:00 PM -8:00 AM): \$18/hour for 300-baud service; \$36/hour for 1200-baud service. Telenet, Tymnet, or Uninet charges are included in the above rates, except from Alaska and Hawaii.

Comments: NewsNet offers over 150 industry and professional newsletters.

## APPENDIX D - PRINTED SOFTWARE DIRECTORIES

Among numerous general purpose printed software directories that are published, the following list is a narrowed selection of directories that are exclusively, or at least partially, oriented towards software applications in civil engineering or computer graphics. Some of the listed directories are hardware specific, but most are a collective listing of software available for different hardware setups. The list was compiled from Glossbrenner's How to Buy Software (1984) and from perusing civil engineering periodicals and government document indices.

### Datapro Directory of Microcomputer Software

Datapro Research Corporation  
1805 Underwood Blvd.  
Delran, NJ 08075  
(800) 257-9406  
(609) 764-0100, in New Jersey

Price: \$420 for annual subscription; extensive updates issued monthly.

Comments: This software directory is one of the most comprehensive listing of available software that is published. The directory contains over 52 tabbed software categories, each of which contains subcategories. Product listings include requirements for operating systems and hardware, in addition to 200 to 300 word descriptions supplied by the software producer.

Master indices are organized by product name, application, and software vendor. Descriptions include a vendor profile, a user rating section, and references to feature reports containing in-depth software review articles. Each month, subscribers receive packets containing 50-100 pages of updated information. Finally, the subscription includes an "Inquiry Service" for obtaining more technical information on listed software or for conducting software searches. The directory is expensive for individuals, but is affordable for libraries and corporations.

### The Infopro Directory

Infopro, Inc.  
P.O. Box 22  
Bensalem, PA 19020  
(215) 750-1023

Price: Not specified

Comments: "The Directory of Independent IBM Personal Computer Hardware and Software." This directory is published as a three-ring notebook (8 1/2" x 5 1/2") which contains information on hardware and software for the IBM-PC.

Many entries include "review/comment" sections written by Infopro staff. Additional information can be obtained through telephone consultations which are generally free, except for costs of photocopying or mailing any supplemental material.

The PC Clearinghouse Software Directory

PC Clearinghouse, Inc.  
11781 Lee-Jackson Highway  
Fairfax, VA 22033  
(800) 368-4422  
(800) 552-4422, in Virginia

Price: \$29.95; 15-day money-back guarantee

Comments: Over 21,000 software products are cross-referenced by hardware, operating systems, application, price, and microprocessor. Entries include system name and compatible hardware, and vendor information.

The Software Catalogue

Elsevier Science Publishing Co.  
52 Vanderbilt Avenue  
New York, NY 10017  
(800) 223-2115, 9 AM-9 PM, EST  
(212) 867-9040, in New York, 9 AM-5 PM, EST

Price: Two editions yearly, \$69 each; updates are \$15.

Comments: This directory is available in two versions, one for microcomputers (\$69; about 800 pages) and one for minicomputers (\$95, about 560 pages). Over 10,000 software entries are cross-referenced by type of computer, application, operating system, keywords, vendor, type of processor chip, and general subject. International Standard Program Numbers (ISPN) designations are used.

Software in Print

Technique Learning  
40 Cedar Street  
Dobbs Ferry, NY 10522  
(914) 693-8100

Price: not specified

Comments: This directory is equivalent to R.R. Bowker's Books in Print series. Programs are assigned a Universal Software Market Identifier (USMI) number which identifies the software vendor, application, required hardware, and other program points.

The Software Source

Software Source, Inc.  
2701 CW 15th Street-Suite 109  
Plano, TX 75075  
(800) 621-5199  
(800) 972-5855, in Illinois

Price: \$26.95. Updates included.

Comments: Directory is published as a three-ring notebook containing over 400 pages divided into 16 or more tabbed sections. Each page is formatted as three columns showing the program name, description, and required hardware. Programs are indexed by name and software house.

Hunt's Directory

Hunt and Associates  
2250 Morello Avenue  
Pleasant Hill, CA 94523  
(415) 671-0382

Price: \$50

Comments: This directory lists over 1000 descriptions of microcomputer software available for civil engineering applications. Software is listed for most microcomputers and operating systems, and is organized by engineering discipline.

Softwhere

Softwhere Moore Data Management Services  
1660 South Highway 100  
Minneapolis, MN 55416  
(800) 328-5727, ext. 6203  
(800) 742-5685, ext. 6203, in Minnesota

Price: \$29.95

Comments: This directory is a listing of software applicable to the engineering profession. Software is categorized by engineering disciplines which include the relevant topics of civil engineering design and analysis, surveying and mapping, and modeling and simulation.

A Directory of Computer Software

U.S. Department of Commerce  
National Technical Information Service  
5285 Port Royal Road  
Springfield, VA 22161

Price: not specified

## APPENDIX E

### EDITING PROCEDURES FOR THE CIVILSOFT CONTOUR PROGRAM USING WORDSTAR AND LOTUS 1-2-3

Use of WordStar 3.3 wordprocessing software and LOTUS 1-2-3 spreadsheet software enables extensive editing to be performed upon CIVILSOFT CONTOUR or EARTHWORK II data files. The following procedure was used in the evaluation to interchange "x" and "y" data columns for 615 points for the CONTOUR file, "TCCONT25".

The first part of the editing procedure uses WordStar 3.3 in non-document mode to prepare the data file for export to LOTUS 1-2-3. WordStar does not allow block moves in non-document mode.

1. Using the IBM DOS command "copy", make a duplicate file for editing with a ".prn" extension.

B> copy file.dat file.prn

2. Enter WordStar and select the non-document mode, "n", to open the data file for export preparation.
3. In order for data labels to be exported along with the columns of numbers, enclose the first two file header lines and the last five footer lines with quotation marks as shown.

"TITLE	TIMBERCREEK II"						
"POINTS	450.	25.	700.	50.	650.	109.	127.3"
	475.		650.		126.35		129.
			650.				
	500.		650.		126.63		
	525.		650.		125.34		
	650.		50.		111.23		
"9999"							
"TRIANGLE"							
"CONTOURS				100.	1.	5.	9. 108. 128.
"PLOTUTIL				100.	0.	0.	0. 0. 0 0 .12"
"END"							0"

4. Close the data file using \*KD.

Next, LOTUS 1-2-3 is used so extensive editing can be performed using the move commands.

5. Enter LOTUS 1-2-3 and import the print file previously prepared through WordStar using the following menu commands:

/ File Import Numbers File Name

Note that the file header and footer lines that are enclosed in quotes are treated as labels and are imported into LOTUS 1-2-3 in the correct positions, but columns of numbers are shifted to correspond to the worksheet column widths.

6. Using the LOTUS 1-2-3 "Move" commands, interchange data columns or do any editing as needed.

Since integers are imported into LOTUS 1-2-3 without any decimal points, it is necessary to append decimal points after all integers before the column widths are adjusted to match the original file configuration. Since data files may be long, appending decimal points can be accomplished through the following LOTUS 1-2-3 macro routine:

7. Cell Address	Macro Line
J2	'/c J1'
J3	'/xiJ1=0#or#J1=9999'/xq_
J4	'/xiJ1-@int(J1)=0'/xgM4
J5	{down}/xgJ2
M4	{edit}{home}"{end}.'
M5	{down}/xgJ2

Note: Apostrophes (') proceeding the slash (/) at the beginning of a cell are used to distinguish a macro command from menu summoning. The apostrophes will not appear on the worksheet, but are displayed in the cell listings.

8. Name the macro using the menu command sequence:

/ Range Name Create \Z J2

where \Z = macro name  
J2 = cell where the macro begins

9. Position the cursor at the beginning of each data column and activate the macro by pressing "Alt Z".
10. Before adjusting the column widths, make a worksheet copy of the results up to this point using the "File Save" sequence.
11. Adjusting the column widths to match the original file configuration may take some experimentation (hence the worksheet copy). The column widths should be set around 15, but this will vary depending upon whether the data for each column were integers, decimals, or a mixture of the two. A printed copy of the first and last page of the original file is suggested for comparison.

12. Print the worksheet to a print file:

/ Print File Range Options Align Go

Notes: - The Range should be set to include the entire worksheet except the macro sequence.

- Using the Options menu command, reset the left margin to 0.

13. Re-open the file using WordStar "n" mode for final "cleanup"

- Verify that the columns of numbers (with decimal points) are positionally correct.
- Delete extra lines at the top of the file and throughout the file where "page breaks" occurred in LOTUS 1-2-3.

14. Exit WordStar and rename the print file back to a data file:

B>rename file.prn file.dat

15. The file should now be ready for use by the CIVILSOFT programs.

## APPENDIX F

### CIVILSOFT - PROGRAM OUTPUT

#### CONTOUR Program

---

##### Graphs

- |     |  |     |
|-----|--|-----|
| F.1 | Contour plot of existing topography . . . . .  | F-1 |
| F.2 | Contour plot of existing topography defined with<br>additional random points . . . . . | F-2 |

#### EARTHWORK II Program

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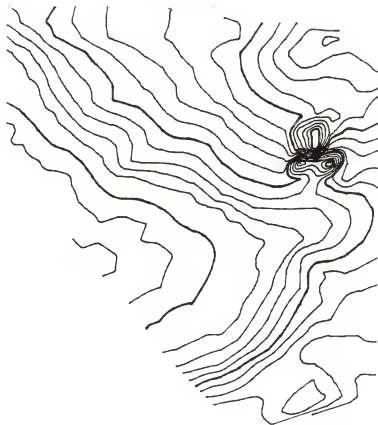
##### Tables

- |     |  |     |
|-----|--|-----|
| F.1 | Sample station earthwork calculations . . . . .  | F-3 |
| F.2 | Earthwork summary (subcut and subfill) . . . . . | F-4 |

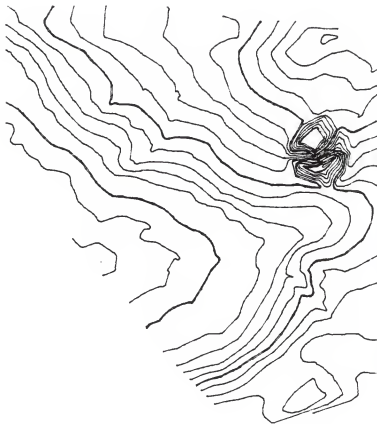
##### Graphs

- |     |   |     |
|-----|---|-----|
| F.3 | Screen dump of graphed cross section 2+82 . . . . . | F-5 |
| F.4 | Pen plot of graphed cross section 2+82 . . . . .    | F-6 |





Graph F.1 - CIVILSOFT CONTOUR plot of existing Timbercreek II topography based on a regular 25' grid.



Graph F.2 - CIVILSOFT CONTOUR plot of existing Timbercreek II topography in which additional, random spot elevations have been included to more accurately model unusual topographic features.

Table F.1 - Sample incremental earthwork volumes calculated between Stations 2+22 and 2+82 using the CIVILSOFT EARTHWORK II program.

\*\*\*\*\* Earthwork Calculations By Average End Area Method \*\*\*\*\*

Project : Timbercreek II Earthwork Estimate

Station : 282.0

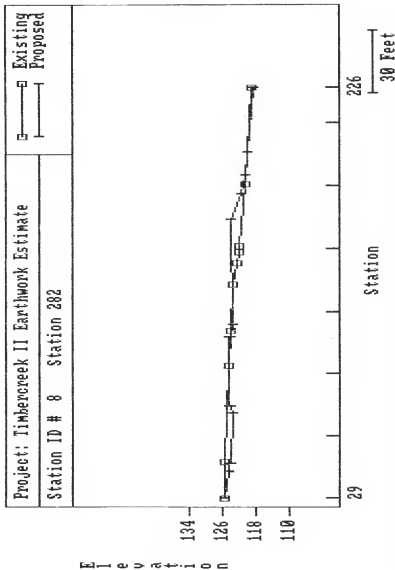
Existing Profile Data			Future Profile Data		
Point	X-Value	Y-Value	Point	X-Value	Y-Value
1	29.00	125.70	1	29.00	125.70
2	47.00	125.40	2	29.01	125.50
3	93.00	124.50	3	42.00	124.40
4	110.00	124.20	4	46.00	124.60
5	132.00	123.70	5	46.01	123.80
6	142.00	122.50	6	70.00	123.50
7	147.00	122.00	7	73.50	123.85
8	150.00	121.80	8	73.51	124.35
9	180.00	120.40	9	107.00	124.30
10	226.00	118.90	10	107.01	123.95
			11	113.00	123.60
			12	163.00	123.80
			13	175.00	121.50
			14	184.00	120.50
			15	195.00	119.95
			16	225.90	118.60
			17	226.00	118.90

Cut Area In Square Feet	=	73.2
Fill Area In Square Feet	=	76.0
Cut Volume In This Reach In Cubic Yards	=	184.6
Fill Volume In This Reach In Cubic Yards	=	95.3
Total Cut Volume In Cubic Yards	=	1737.1
Total Fill Volume In Cubic Yards	=	112.8

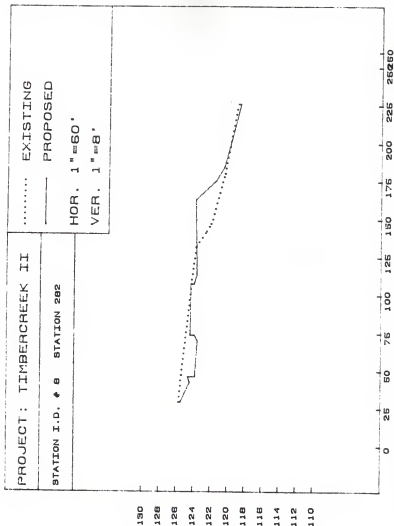
Table F.2 - Earthwork summary for Timbercreek II using the CIVILSOFT EARTHWORK II program.

Earthwork Summary For Timbercreek II Earthwork Estimate  
Average End Area Method

Station (Ft)	Area Of Cut (Sq.Ft)	Area Of Fill (Sq. Ft)	Incremental Volume Of Cut (Cu.Yd)	Incremental Volume Of Fill (Cu. Yd)	Total Volume Of Cut (Cu.Yd)	Total Volume Of Fill (Cu. Yd)
0.0	0.0	0.0			0.0	0.0
31.0	5.8	0.0	3.3	0.0	3.3	0.0
39.0	91.1	0.0	14.4	0.0	17.7	0.0
81.0	346.3	0.0	340.2	0.0	357.9	0.0
137.0	287.1	5.8	656.9	6.0	1014.8	6.0
188.0	132.1	0.0	396.0	5.4	1410.7	11.4
222.0	93.0	9.7	141.7	6.1	1552.5	17.5
282.0	73.2	76.0	184.6	95.3	1737.1	112.8
299.0	206.3	30.6	88.0	33.6	1825.1	146.4
353.0	119.8	48.5	326.1	79.1	2151.2	225.5
409.0	67.4	181.2	194.2	238.3	2345.4	463.8
426.0	65.0	197.1	41.7	119.1	2387.1	582.9
516.0	54.2	282.7	198.6	799.7	2585.7	1382.6
537.0	23.9	250.1	30.4	207.2	2616.1	1589.8
585.0	9.6	27.0	29.8	246.4	2645.9	1836.2
605.0	5.7	0.0	5.7	10.0	2651.5	1846.2
620.0	0.0	0.0	1.6	0.0	2653.1	1846.2



Graph F.3 - Screen dump of Timbercreek II cross-section 2+82 using the CIVILSOFT EARTHWORK II program. Screen plots are sometimes hard to read because no vertical exaggeration is offered.



Graph F.4 - A CIVILSOFT EARTHWORK II pen plot of Station 2+82 in which the horizontal and vertical scales are individually selectable.

## APPENDIX G

### MFE ASSOCIATES - PROGRAM OUTPUT

#### EARTHWORKS II Program

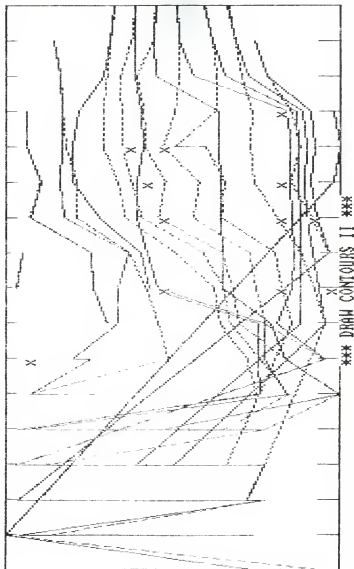
---

##### Graphs

- G.1 Screen dump of station-by-station contour plot . . . . . G-1
- G.2 Screen dump of graph of cross-section 2+82 . . . . . G-6

##### Tables

- G.1 Screen dump of x,y existing data - Station 2+82 . . . . . G-2
- G.2 No-cut/no-fill points for Stations 0 through 4+09 . . . . . G-3
- G.3 Earthwork summary based on drawn cross-sections . . . . . G-4
- G.4 Earthwork summary based on data measured from baseline . . . . . G-5



Graph G.1 - A screen dump of a station-by-station contour plot of the Timbercreek II site using the MFE EARTHWORKS II program. High distortion, as evident in the leftmost stations, occurs when contour lines run nearly parallel to section lines.



Table G.1 - Screen dump of listing of x,y values defining the existing grade for Station 2+82 using the MFE EARTHWORKS II program.

Existing Conditions: X and Y Coordinates.

Location ID No. B		Station		282.00	
LINE	VARIABLE	VALUE	VARIABLE	VALUE	
1	X( 1 ) =	24	Y( 1 ) =	125.7	
2	X( 2 ) =	47	Y( 2 ) =	125.4	
3	X( 3 ) =	93	Y( 3 ) =	124.5	
4	X( 4 ) =	110	Y( 4 ) =	124.2	
5	X( 5 ) =	132	Y( 5 ) =	123.7	
6	X( 6 ) =	142	Y( 6 ) =	122.5	
7	X( 7 ) =	14	Y( 7 ) =	120	
8	X( 8 ) =	150	Y( 8 ) =	121.8	
9	X( 9 ) =	180	Y( 9 ) =	120.4	
10	Y( 10 ) =	226	Y( 10 ) =	118.9	

FILE RETURN to continue

Table G.2 - No-cut/no-fill points where existing and proposed grades intersect are listed for Station 0 through Station 4+09.

---

LOCATION OF NO-CUT/NO-FILL POINTS

FOR FILES: B:timbewe.EW

TIMBERCREEK II EARTHWORK ESTIMATE (Existing Grade)

AND: B:timbewp.EW

TIMBERCREEK II EARTHWORK ESTIMATE (Proposed Grade)

SECTION AT 0

0 , .9 , 1.55

SECTION AT 31

5 , 1.6 , 3.7 , 6

SECTION AT 39

12.5 , 6.3 , 7.7 , 16.8

SECTION AT 81

7 , 19.7

SECTION AT 137

14 , 19.8 , 22.1

SECTION AT 188

13 , 20.3 , 21.4 , 22.201

SECTION AT 222

24 , 12.8 , 14.6 , 16 , 19 , 21 , 22.201

SECTION AT 282

29 , 10.408 , 10.7 , 13.219 , 19.853 , 22.6

SECTION AT 299

30 , 15.362 , 21.405 , 22.5

SECTION AT 353

51 , 14.2 , 21.1 , 21.701

SECTION AT 409

14 , 9.367 , 24.3

Table G.3 - Earthwork summary table for subcut and subfill quantities based on x,y values derived from graphically drawn cross-sections.

---

CUT AND FILL CALCULATIONS FOR  
DATA FILES : B:timbewe.EW AND B:timbewp.EW

BETWEEN STATIONS	CUT VOLUME CU.Ft.	FILL VOLUME CU.Ft.
0		
	89.4	0
31		
	387.6	0
39		
	9185.5	0
81		
	17735.9	161
137		
	10691.3	146.6
188		
	3826.6	165.6
222		
	4985.3	2572.6
282		
	2375.7	906.4
299		
	8805.1	2136.5
353		
	5242.8	6432.8
409		
	1125.3	3215.9
426		
	5363.4	21592.7
516		
	820.1	5595.1
537		
	803.3	6651.8
585		
	152.7	270.2
605		
	42.7	0
620		
TOTAL	71632.7	49847.2

TOTAL CUT VOLUME: 2653.06 CU.Yd.  
TOTAL FILL VOLUME: 1846.19 CU.Yd.  
RATIO OF CUT TO FILL: 1.437046  
END OF RUN

Table G.4 - Earthwork summary table for cut and fill quantities using x,y values directly measured off a grading plan using a baseline.

CUT AND FILL CALCULATIONS FOR  
DATA FILES : B:ewbaseex.EW AND B:ewbasepr.EW

BETWEEN STATIONS	CUT VOLUME CU.Ft.	FILL VOLUME CU.Ft.
0	0	193.7
31	0	50
39	5250	0
81	17841	0
157	3829.6	24.3
188	1354.8	173.3
222	2381.4	3386.4
282	1572	1386.7
299	6444.6	3534.1
353	3282.3	8836.1
409	764.9	4309.8
426	3437.1	27635.1
516	418	7095.5
537	456.1	9069.7
585	17.9	547.9
605	0	15
620		
TOTAL	47049.7	66257.6

TOTAL CUT VOLUME: 1742.58 CU.Yd.  
TOTAL FILL VOLUME: 2453.98 CU.Yd.  
RATIO OF CUT TO FILL: .7101036  
END OF RUN

\*\*\* CUT & FILL II \*\*\*  
SECTION AT: 282

El= 118.2

El= 125.7



El= 118.9

VERT. EXAGG.= 2.5 x  
(MAX. EL= 125.7 MIN. EL= 118.6 )  
29 , 104.086 , 107.001 , 132.193 , 198.531 , 226

Graph G.2 - A screen dump of Timbercreek II Station 2+82 using the MFE EARTHWORKS II program in which no-cut/no-fill points are calculated and vertical exaggeration is selectable. Plot shortcomings include the 118 number in the upper right corner left over from a previous plot and no elevational numbering along the vertical axis.

## APPENDIX H

### PACSOFT - PROGRAM OUTPUT

#### TOPOGRAPHY Digital Terrain Modeling System

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##### Graphs

H.1	ROUGH CONT plot of existing topography . . . . .	H-1
H.2	ROUGH CONT plot of proposed topography . . . . .	H-2
H.3	SMOOTH CONT plot of existing topography . . . . .	H-3
H.4	SLOPE graph of slope steepness percentages . . . . .	H-4
H.5	Drainage map of arrows pointing downhill (VECTOR) . . .	H-5
H.6	Rotated 3D views of existing topography (3D GRID) . . .	H-6
H.7	Three-dimensional views of existing and proposed Timbercreek II topography (3D GRID) . . . . .	H-7
H.8	Proposed topography plotted at 5:1 & 10:1 vertical exaggeration (3D GRID) . . . . .	H-8
H.9	Superimposed 3D plots of existing and proposed topography showing earthwork (3D GRID) . . . . .	H-9
H.10	Three-dimensional contour line plot (3D CONT) . . . . .	H-10
H.11	Timbercreek II site layout plotted in plan view to verify plot file accuracy (3D PLAT) . . . . .	H-11
H.12	Projection of Timbercreek II site layout on 3D plot of proposed topography (3D GRID & PLAT) . . . . .	H-12
H.13	Profile plot of existing topography along proposed parking bay centerline (PROFILE) . . . . .	H-13
H.14	Cross-sectional plots taken every 25' along profile line (XSECT) . . . . .	H-14

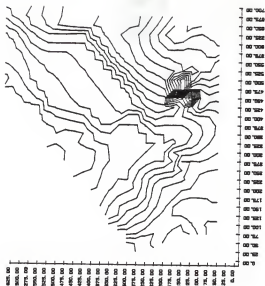
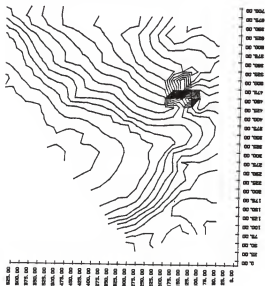
Table H.1 - Price list for the PacSoft TOPOGRAPHY Digital Terrain Modeling system.

Options	TOPOGRAPHY Option	Series 200	9845	Series 80
Base System		\$1000	\$1000	\$800
Option 001	Contour Mapping	750	750	650
Option 002	Profiles & Cross Sections	600	600	550
Option 003	3-D Projections	450	450	400
Option 004	Earthwork Volumes	750	750	650
Option 004a	Plotting for Option 004	300	300	250
Option 005	Data Transfer/Other EM systems	*	---	300
Option 006	Digitized Modeling	350	350	300
Option 007	Interactive Modeling	500	500	450
Option 008	Slope Shading	600	600	500
Option 009	Vector	400	400	350
Option 010	3-D Plat	750	750	600
Option 011	Grid Math	450	450	400
Option 012	Template	600	600	500

\* Contact PacSoft for information on availability

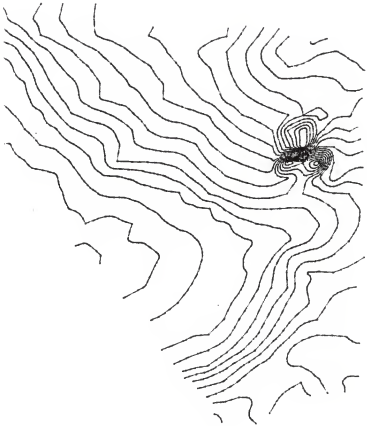
- Prices effective September 1, 1984

- There is a 10% discount on when 5 or more options are purchased in a single order.

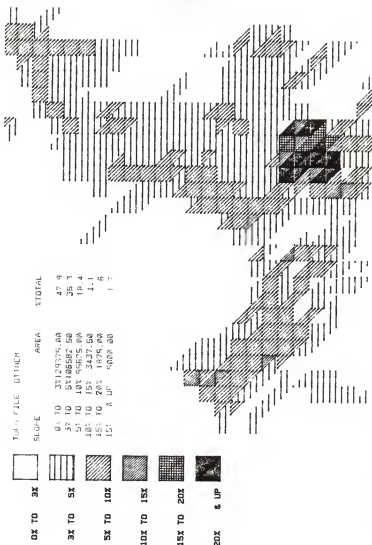


Graphs H.1 and H.2 - Plots of existing and proposed contours of the Timbercreek II site using the PacSoft ROUGH CONT program. The zig-zag lines of some proposed contours result from modeling based on grid point sampling.

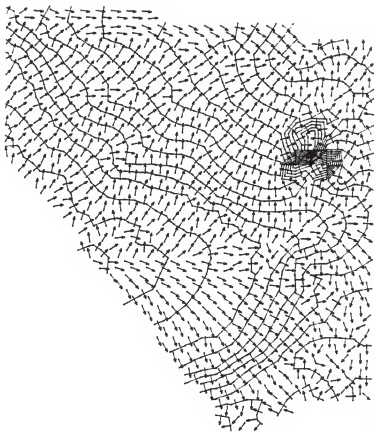




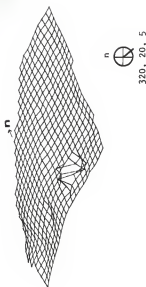
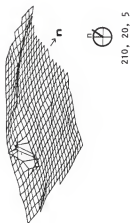
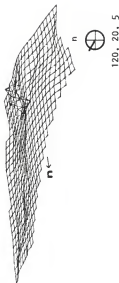
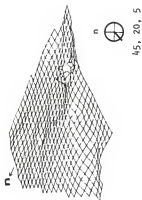
Graph H.3 - A plot of existing Timbercreek II topography using the PacSoft SMOOTH CONT program.



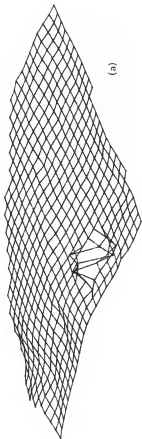
Graph H.4 - Map generated by PacSoft SLOPE program in which Timbercreek II existing topography is categorized and plotted to correspond to six slope percentage categories.



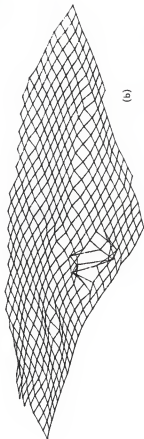
Graph H.5 - Drainage map produced by superimposing drainage arrows (VECTOR program) on a plot of existing topography (ROUGH CONT program). Drainage arrows point downhill.



Graph H.6 - Rotated three-dimensional views of the Timbercreek II existing topography using the PacSoft 3D GRID program.

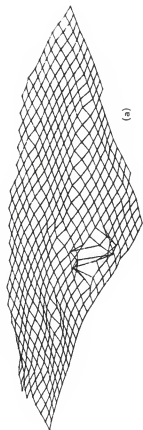


(a)

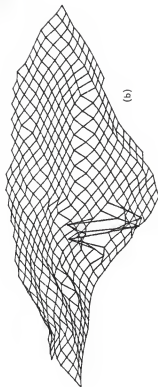


(b)

Graph H.7 - Three-dimensional views of existing topography (a) and proposed topography (b) for the Timbercreek II site using PacSoft 3D GRID.

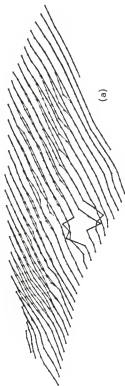


(a)

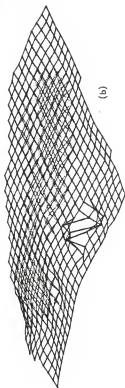


(b)

Graph H.8 - Three-dimensional views of proposed Timbercreek II topography at 5:1 exaggeration (a) and 10:1 exaggeration (b) using PacSoft 3D GRID.

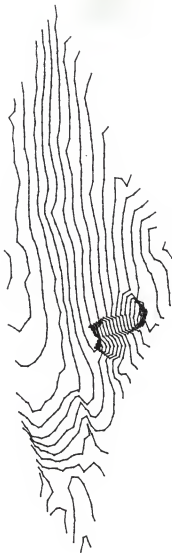


(a)



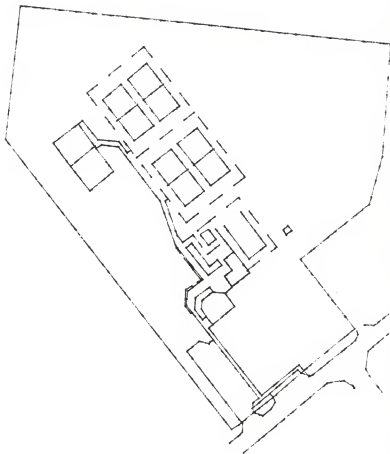
(b)

Graph H.9 - Superimposed three-dimensional landform plots of both existing and proposed topography intended to show grade level differences using one-dimensional sectional plotting (a) and bidirectional surface plotting (b) using PacSoft 3D GRID. Existing and proposed topography surfaces can be plotted in different colors for improved clarity.

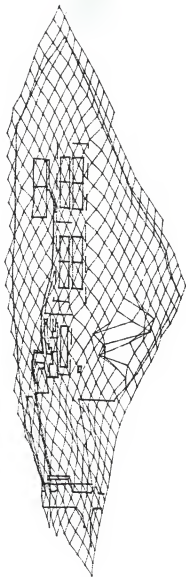


Graph H.10 - Three-dimensional contour line plot of existing Timbercreek II topography using PacSoft 3D  
CONT program.

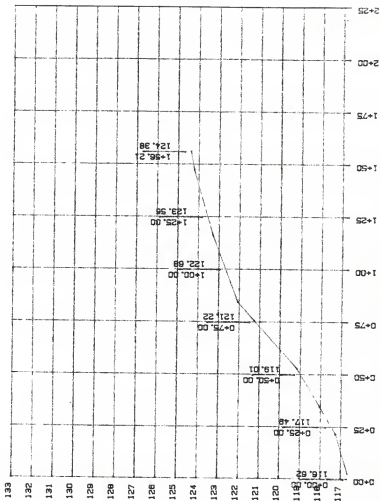




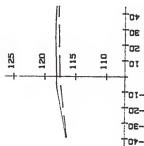
Graph H.11 - Plan view of Timbercreek II layout used to verify plot accuracy before three-dimensionally superimposing the layout on proposed topography.



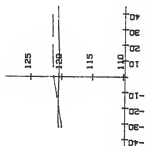
Graph H.12 - Projection of Timbercreek II site layout on three-dimensional view of proposed topography using the PacSoft 3D PLAT and 3D GRID programs.



Graph H.13 - Profile pen plot of existing topography (FacSoft PROFILE) along the centerline of the proposed parking bay extending northeast from Coachman Road. A profile plot can follow a baseline including both straight and curved segments.



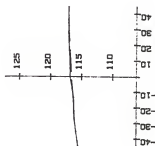
0+25.0



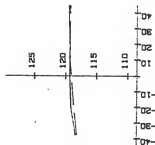
0+75.0



1+25.0



0+00.0



0+50.0



1+00.0

Graph H.14 - Cross-sectional plots (PacSoft XSECT) of existing and proposed topography taken along the profile line at 25 foot station intervals.

APPENDIX I  
HARDWARE AND SOFTWARE USED

HARDWARE USED

IBM Corporation  
IBM Personal Computer  
Sales and Service  
P.O. box 1328-C  
Boca Raton, FL 33432  
(800) 447-4700

IBM Personal Computer PC & XT (256 K)  
IBM Color Display

Enter Computer, Inc.  
6867 Nancy Ridge Drive  
San Diego, CA 92121  
(619) 450-0601

Model SP600 Pen Plotter (Sweet-P)

Epson America, Inc.  
3415 Kashiwa Street  
Torrance, CA 90505  
(313) 539-9140

Epson FX 100 Dot Matrix Printer

Hewlett-Packard, Inc.  
Personal Computer Division  
1010 NE Circle Blvd.  
Corvallis, OR 97330  
(800) FOR-HPPC

HP 87 Microcomputer (64K), ROM Drawer  
HP 82901 M Dual Disc Drive  
HP 9111A Graphics Tablet  
HP 7470A Two-pen Plotter  
HP Thinkjet Printer

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SOFTWARE USED

CIVILSOFT  
290 S. Anaheim Blvd., Suite 100  
Anaheim, CA 92805  
(714) 999-5001

CONTOUR program  
EARTHWORK II program

MFE Associates, Inc.  
P.O. Box 851  
Amherst, Massachusetts  
(413) 253-7066

EARTHWORKS II program

PacSoft, Incorporated  
330 Fourth Street  
Kirkland, WA 98033  
(206) 827-0551

TOPOGRAPHY DTM system

SOFTWARE - Continued

MicroPro International Corp.  
33 San Pablo Avenue  
San Rafael, CA 95903  
(415) 449-1200

WordStar 3.3 Wordprocessing program

Lotus Development Corporation  
161 First Street  
Cambridge, MA 02142  
(617) 492-7171

LOTUS 1-2-3 Spreadsheet program

MICROCOMPUTER-ASSISTED SITE DESIGN IN LANDSCAPE ARCHITECTURE:  
EVALUATION OF SELECTED COMMERCIAL SOFTWARE

by

HOWARD DAVIS HAHN

B.G.S., University of Kansas, 1981

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AN ABSTRACT OF A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF LANDSCAPE ARCHITECTURE

Department of Landscape Architecture

KANSAS STATE UNIVERSITY  
Manhattan, Kansas

1985

## ABSTRACT

Landscape architects are in need of an integrated computer-assisted site design (CASD) software package. Such a system should employ a three-dimensional computer image of landform based on a triangulated irregular network (TIN). Import of program modules such as grading, road alignment, piped utility systems, and site layout would be graphically and computationally linked to the topographic base for site modeling. The purpose of this research was to evaluate current contouring and earthwork calculation software available to landscape architects in relation to the idealized CASD package. Three companies participated by submitting software for evaluation: CIVILSOFT, MFE Associates, and PacSoft. Software was evaluated in the five categories of Performance, Ease-of-Use, Error Handling, Documentation, and Application to Landscape Architecture.

For estimating earthwork quantities using the average-end technique, the CIVILSOFT and MFE programs yielded accurate results that were within 99.9% of the net earthwork balance calculated through manual methods using planimetered cross sections. Both programs are time- and cost-effective. The CIVILSOFT CONTOUR program yielded excellent results because of the program structure which creates a triangulated network of random points that can be concentrated where most needed to accurately define unusual topography. A pen plotter which accepts 24"x 36" paper is recommended if the CONTOUR program is to be used to create full-size site base maps. All programs offered by CIVILSOFT and MFE Associates were run on IBM-PC hardware systems.

The TOPOGRAPHY software marketed by PacSoft, and adapted to Hewlett Packard microcomputers, is a digital terrain modeling package which utilizes a rectangular grid system. Integrated program modules particularly useful to landscape architects include a three-dimensional "fishnet" depiction of landform, calculation of earthwork between any two surfaces, topographic profile and cross-section plotting, and three-dimensional plating in which plan view drawings can be superimposed on the 3D landform plot. The TOPOGRAPHY software was judged to be most useful for analyzing site designs first worked out on paper and then transferred to the computer system. It would be difficult for landscape architects to do actual site design on the computer because the TOPOGRAPHY system does not support interactive screen graphics. Landscape architects should at least consider the TOPOGRAPHY package if three-dimensional modeling is to be performed on a microcomputer hardware system.

Data entry for all of the software evaluated was tedious and time-consuming. The TOPOGRAPHY package was the most convenient to use because data could be optionally entered through a digitizer. None of the software, however, can be considered a highly interactive design tool. Until a CASD package is specifically written for landscape architects, they will continue to design with pencil and paper in the immediate future.